COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

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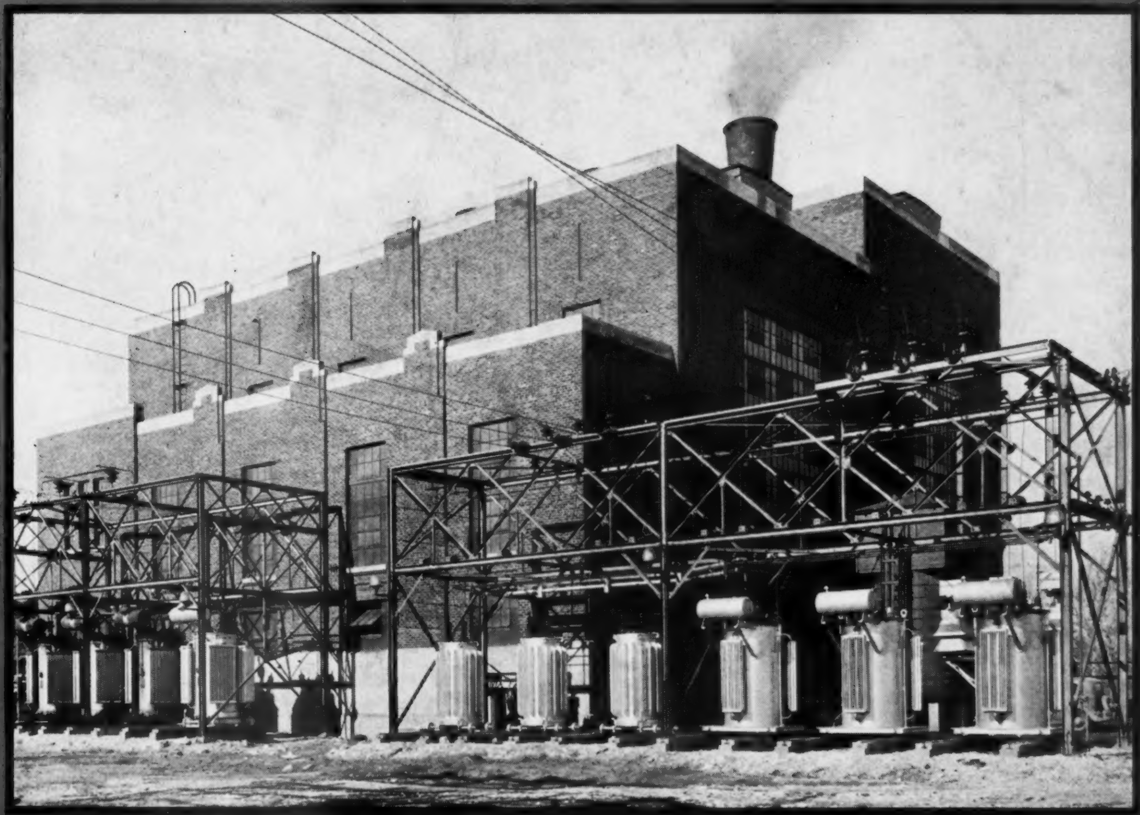

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What a Third of a Century of Turbine Lubrication Experience Shows

Alloy Steels for Temperatures over 800 F in Boiler Drums, Superheaters and Steam Piping

COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

VOLUME SEVEN | NUMBER ONE

CONTENTS

FOR JULY 1935

FEATURE ARTICLES

EDITORIALS

DEPARTMENTS

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BOOKS

1—Power Plant Testing (Fourth Edition)

By JAMES A. MOYER

614 pages Price $5.00

For a number of years this book has been widely accepted as a reference and guide in power plant testing. Since the appearance of the third edition in 1926 advances in power plant practice have been such as to warrant certain refinements in testing, in accordance with standards recommended by the engineering societies. This is particularly true of temperature and pressure measurements and in certain phases of steam turbine work.

The present edition, while retaining the fundamental material contained in the earlier editions, has been partly rewritten and amplified to include the new codes and testing methods as recommended by the Power Test Codes Committee of the A.S.M.E. and by other societies. A large number of engineers and teachers have contributed toward this revision.

The scope of this book, as indicated by a partial list of chapter headings, is as follows: Measurement of Pressure; Measurement of Temperature; Determination of the Moisture in Steam; Measurement of Areas; Measurement of Power—Dynamometers; Flow of Fluids; Flue-Gas Analysis; Testing of Boilers and Other Steam-Generating Units; Testing Steam Turbines and Turbogenerators; Tests of Complete Steam Power Plants—Coal Fired; Gas- and Oil-Engine Producer Testing; Testing of Ventilating Fans, or Blowers and Air Compressors; Testing of Lubricants; Testing of Governors.

2—A.S.M.E. Power Boiler Code 1933 Edition

314 pages $5\frac{1}{2} \times 8$ Price $2.50

The latest edition of the *A.S.M.E. Power Boiler Code* incorporates the revisions, extensions and additions to rules and specifications that have been made during the past three years. It contains Sections I, II and VI of the *A.S.M.E. Boiler Construction Code*, covering respectively, Power Boilers, Material Specifications and Rules for Inspection. Also includes 1934 Addenda sheets.

3—Practical Everyday Chemistry

By H. BENNETT

303 pages Price $2.00

Despite the title, this is not a simplified book on chemistry as one usually regards the subject with its numerous chemical formulas, reactions, etc. Instead, it is based on the fact that most everything we use in daily life is either a chemical mixture or involves some form of chemistry in its process of manufacture. These numerous products are often effectively disguised under trade names, and their composition and methods of manufacture hold general interest for those of an inquiring mind. The chapter on materials of construction should, in particular, provide a handy reference for many engineers.

Among the other subjects discussed in this book are the following: adhesives; agricultural and garden specialties; coatings, protective and decorative; food products, beverages and flavors; inks, carbon paper, crayons, etc.; lubricants, oils, etc.; paper; photography; plating; abrasives, etc.; rubber, plastics, waxes, etc.; textile and fibers.

This book contains 303 pages, size $5^1/_2 \times 8$. Price $2.00.

4—The Design and Use of Instruments and Accurate Mechanism

By T. N. Whitehead

283 pages $6 \times 8^3/_4$ Price $3.50

This book is written for those who design or use instruments and accurate mechanism. It will thus appeal to practical scientists as well as to a large class of engineers.

A somewhat novel analysis of the functioning of accurate mechanism results in a systematic consideration of the principles underlying its design and use.

Professor Whitehead divides into three groups the various errors to which instruments and other precise mechanisms may be liable, each group resulting from a characteristic type of fault in one or more elements. In Part I he discusses these faulty elements and their resulting errors; in Part II he considers these defects in relation to practical problems of design and use.

5—Mathematical Tables

Compiled by Charles D. Hodgman

237 pages $5^1/_4 \times 7^3/_4$ Price $1.50
$4^1/_8 \times 6^3/_8$ $1.00

This is the third edition of the collection of mathematical tables and formulae which, although different in form, is identical in content with the mathematical section of the 18th edition of the Handbook of Chemistry and Physics.

Among the tables and formulae contained in this book are the following: Algebraic Formulae; Mensuration Formulae; Trigonometrical Functions in a Right-Angled Triangle; Relations Between Sides and Angles of Any Triangle; Differentials; Integrals; Analytical Geometry; Four-Place Logarithms; Five-Place Logarithms; Hyperbolic Functions; Degrees, Minutes and Seconds to Radians; Degrees and Decimals to Radians; Decimal Equivalents of Common Fractions; Numerical Constants; Logarithmic Constants; Interest Tables.

6—Chemical Engineers' Handbook

By Dr. John H. Perry and W. S. Calcott
Assisted by a staff of specialists

2609 pages 5×7 Price $9.00

A handbook for the practicing engineer in the field of chemical and process industries. In this field it forms a companion treatise to Marks in the mechanical engineering field. Sixty-three specialists in various branches have contributed to the thirty sections of the book. Mechanical and electrical engineering, such as power generation and application, transmission, fuels, refrigeration, materials of construction, etc., are dealt with to the extent of acquainting the chemical engineer with fundamentals, types and performance to be expected. Conversely, the mechanical engineer will find the book of great assistance in affording a knowledge of processes that utilize the services for which he is responsible.

7—Combustion in the Power Plant (A Coal Burner's Manual)

By T. A. Marsh

255 pages Price $2.00

The author's discussion of coals and combustion is simple and understandable. His consideration of equipment—stokers, boilers, furnaces, fans and auxiliaries—is thoroughly practical. He tells how to select a stoker for the best available coal; how to design furnaces and arches; how to analyze draft problems and design chimneys, gas flues and boiler passes; how to purchase coal and calculate steam costs. He gives to every phase of his subject a practical interpretation that makes this book of exceptional value to men actually identified with steam plant design and operation.

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EDITORIAL

Federal Aid to Industry

Recovery in the capital goods industries, which has lagged far behind that of the consumer goods industries, should be stimulated by the recent amendment to the Federal Housing Act which provides for individual credits in amounts up to fifty thousand dollars for modernization in industrial equipment. Previously credit had been confined to the housing field.

The amendment liberalizes the security rules, simplifies the procedure and limits the rate of interest. The borrower deals with his local bank or other financial institution and contact with government agencies is unnecessary. The bank, in turn, is protected by a federal guarantee up to twenty per cent of the total of such loans.

Loans are to run for not more than five years and the interest charge is not to exceed the equivalent of five dollars discount per one hundred dollars face amount of a one-year note payable in monthly installments. This means, in effect, that the interest is paid on the full amount of the loan and not on the decreasing indebtedness. At that, the terms are better than those obtaining in many financing set-ups. Moreover, they represent a maximum that cannot be exceeded under the act and the borrower is free to drive a better bargain with his bank if he can.

Over five thousand banks are reported to have agreed to cooperate. If the success of the plan as applied to the building field, which resulted in loans of over four hundred million dollars in amounts up to two thousand dollars, be taken as a criterion, it will find a receptive attitude in the industrial field at a time when industrial operations are handicapped with so much obsolete equipment. This is especially true of the industrial power plant field in which recent surveys have shown a large amount of old and inefficient steam generating and fuel burning equipment.

Obviously, some of the larger industrials are holding up their modernization plans, not through lack of money or credit, but until they can be satisfied as to the effect of current legislation on business. On the other hand, the FHA amendment should ease the credit situation in many instances and enable many of the smaller industrials to proceed with much needed replacements. Moreover, it is likely to stimulate activity in uninsured loans just as it did in the housing field.

The plan should have another far-reaching effect, namely, in providing employment for many mechanical engineers. While the extensive public works program has assisted in the employment of many civil engineers, it has long been apparent that mechanical engineers are dependent largely upon the capital goods industries. Of the many steps taken by the Federal Government to stimulate employment during the past two years, this amendment to the Federal Housing Act is the first from which the mechanical engineer may derive substantial encouragement.

Selection of Accessories

The old adage that "a chain is no stronger than its weakest link," has particular bearing on present power plant practice. In an endeavor to keep down initial investment costs, or to make competitive prices comparable, there is sometimes a tendency to slight the accessories that go with major equipment. When it is considered that outage of a unit, costing many thousand dollars, may result from improper functioning of an accessory costing two or three hundred dollars, or less, the difference of a few dollars in first cost between a proved piece of minor equipment and one of cheaper design and construction becomes insignificant.

Present service demands and the trend toward minimum reserve capacity make reliability paramount and emphasize the importance of materials and workmanship. Experience back of design and servicing facilities are important. Purchasers would do well to keep these points in mind when tempted to trim initial costs.

It is not to be inferred that high cost installations are always justified. This will be determined by the character of the service, which, in turn, governs the refinements that will be warranted. But, having established the general layout, as much attention should be paid to the quality of minor equipment as is accorded that of the larger items entering into the plant design.

Combustion Control in the Smaller Plants

Automatic combustion control has been employed effectively in many large plants for the past ten or twelve years, but until quite recently was not within reach of the smaller industrial power plants because of the complicated designs and the initial cost. Lately, however, several manufacturers of such equipment have developed simplified controls fully meeting the requirements of the smaller plants and available at prices commensurate with those of other equipment in such plants and with the results attainable.

While it has often been claimed, and in some instances demonstrated, that a highly trained boiler room force, giving constant attention to boiler operation, can secure results as good or perhaps better than those obtainable with automatic control, it is evident nevertheless that highly skilled boiler room attendants are the exception in many of the smaller plants. Moreover, in such plants the operator usually has other duties that preclude his giving constant attention to the fires, and with automatic combustion control installed he is free to give more time to other matters that may be essential to operating economy.

With the labor situation as it is and increased coal prices probable in view of pending legislation, these simplified controls should find wide application.

What a Third of a Century of Turbine Lubrication Experience Shows

By CHARLES H. BROMLEY
Lubrication Engineer, Pure Oil Co., New York, N. Y.

The fundamentals of successful steam-turbine lubrication, including a practical discussion of bearing temperatures, viscosity, chemical stability, acidity limits and purification of turbine oils in service. Data are given on the behavior of typical paraffin base oils in service and the curves indicate, by means of sludging machine tests, what may be expected of oils in actual service.

GENERALLY speaking, the steam turbine, particularly in capacities of 1000 kw and over, is now a third-of-a-century old. What then, has experience taught through these thirty-three years? By now it should be known what is good and what is bad practice. And we do know.

Peculiarly, even today, there is a widespread attitude of apprehension about lubricating steam turbines. Certainly the experience gained to date in their operation does not warrant this apprehension. The fact is that the steam turbine is the most easily and perfectly lubricated of all prime movers, if indeed, not all kinds of industrial machinery, provided convenient, inexpensive precautions are followed. The conditions promoting good lubrication are maintained far more constant in the steam turbine than is true of most other kinds of machinery.

Since the days of Beauchamp Tower and Osborne Reynolds it has been known that complete, full fluid film lubrication is the best for any plain journal bearing because such lubrication floats the journal. And so, at all except the very slow speeds at starting and stopping, the journal rides on a liquid lubricant film instead of on the metal of the bearing. The high peripheral speed of the journal, the large volume of oil supplied and the relatively small clearance between the journal and the bearing are conditions ideal to produce and maintain during operation that full fluid film always sought but so seldom attained in the lubrication of industrial machinery generally. The small clearance, together with high speed and plenty of oil, avoids that trouble-promoting condition found so often in lubrication, namely, such excessive leakage of oil from the ends of the bearing that pressure within the film itself is seriously impaired. Therefore, present-day turbine bearing design, the ideal physical and mechanical conditions of normal operation together with the highly suitable oils now available, give little ground for apprehension.

Bearing Pressures Are Low—Steam turbine bearing pressures are low, rarely exceeding 200 lb per sq in., despite the fact that large turbines have rotors weighing 300,000 lb or more. Other kinds of machinery common today have pressures four and five times this amount. But the situation is reversed as to clearance; the turbine bearing has small clearance, usually not exceeding 0.001 in. per inch diameter of shaft. Journal speeds in the steam turbine are, as machinery goes, very high, 10,000 ft per min being common in large units.

Shear Stresses in the Oil Film—In such bearings that part of the oil film in immediate contact with the babbitted surface is stationary. That part of the film in immediate contact with the journal revolves at the journal speed—two miles a minute. Think of the terrific shearing effect in the film, and of the magnitude of the internal friction in the film, even with light viscosity oil. The friction losses in such bearings with journal peripheral speeds of over 10,000 ft per min, as in journals 25 in. diameter at 1800 rpm, are high, being often as much as 175 hp. Therefore, it is of real importance that the viscosity of the oil be kept low, not greater than 150 sec Saybolt at 100 F. Obviously, it is equally important that the oil be supplied in large volume, continuously circulated and cooled. Of course, in large turbines the bearings themselves are water-cooled, there usually being a copper coil imbedded in the babbit metal. Otherwise it would not be possible to avoid excessive bearing temperatures.

About 1923, turbine builders greatly increased the volume capacity of their turbine oil reservoirs, a much-needed improvement. This has helped to give lower bearing temperatures and longer life to the oil.

Temperature Rise in Turbine Bearings—For bearings other than the thrust bearings of modern and large turbine-generators, operating temperatures seldom rise less than 40 deg F and seldom more than 60 deg F over the surrounding room temperature when correctly refined oils of about 150 sec Saybolt at 100 F are used. Higher viscosities give higher temperatures. As bearing temperature is a function of the friction losses and rate of dissipation of the heat generated, temperature becomes an important indicator of safe operation.

Experience is showing that it is good practice to use bearing temperature relays to sound an alarm when the temperature goes slightly above normal. Bearing temperatures should be logged for periodic check-up. Gradually increasing temperature over a long period, allowing for seasonal variations, is cause for suspicion that the bearing may be slightly wiping. With steam turbines serious bearing failures happen quickly. Once the babbit begins to really drag, the temperature rise is rapid and suddenly "it's all over." Obviously, then it is imperative to keep the oil clean at all times, free of even the smallest of solids, as these readily start babbit drag, in a small area perhaps, but that is pretty sure to spread quickly.

STRAY CURRENTS MAY INFLUENCE BABBIT DRAG—Such currents pit the journal and create high spots which may start to wipe the babbit. They will discolor the oil and quicken sludge formation. To avoid these currents bearing pedestals are insulated from the frame. The currents may pit the journal when they short around the insulation due to dirt lodged there. The dirt must be removed, of course, by taking off the bearing and

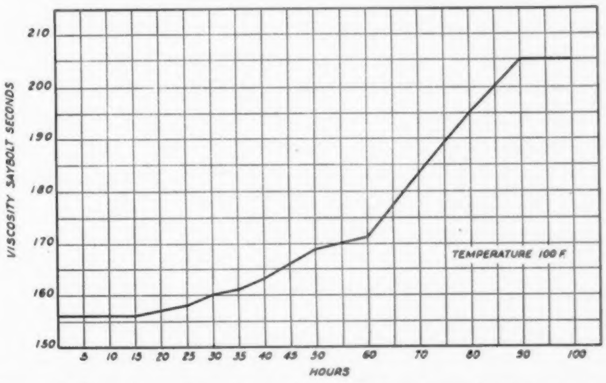


Fig. 1—The viscosity of practically all mineral oils increases in steam turbine service, some faster, some slower than the rate shown here. These results are with the sludging machine

thoroughly cleaning the joint, the area around it and the insulation. Then the insulation should be tested by connecting a 110-volt circuit, with lamps in series, across the insulation.

CLEANLINESS VITAL—Those with considerable turbine lubrication experience know that, given the correct oil, success is chiefly a matter of keeping dirt out of the oil, the cooler, piping and screens, out of the filter and settling tanks, out of turbine room and the basement.

VISCOSITY OF TURBINE OILS—It took a long time to establish what viscosity is most suitable for turbines with circulating oil systems. Now it is known that 150 sec Saybolt is satisfactory. For small turbines with ring-oiled bearings and where the entire oil supply is contained in the bearing housing, filtered cylinder oils of a viscosity range of 140 to 170 sec Saybolt at 210 F are well suited. For geared turbines it is necessary to compromise between what is best for the bearings and what is suitable for the gears. Experience shows that well treated and filtered oils of 300 to 500 sec Saybolt at 100 F cover the range of turbine sizes, gears and their loads. Viscosities of 400 sec and over apply chiefly to geared marine turbines.

CHEMICAL STABILITY IS NECESSARY—Of all that this third-of-a-century of experience has taught the most

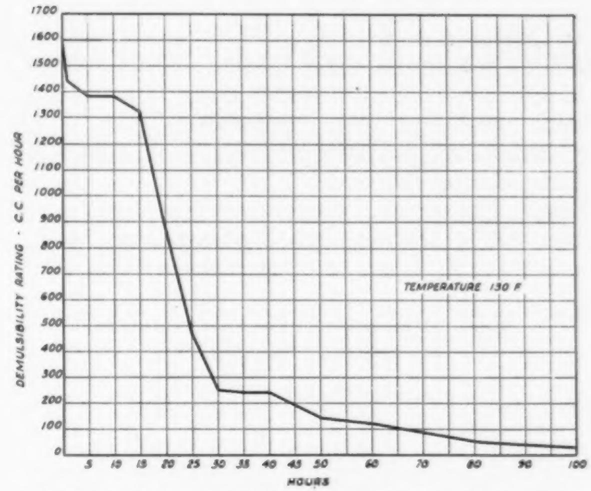


Fig. 2—Typical demulsibility (Herschel) behavior of turbine oil during sludging machine test; test temperature maintained at 130 F

important, next to viscosity, is that chemical stability of the oil is essential. The more of the unsaturated hydrocarbons removed from the oil the greater its chemical stability, the less rapidly will it create sludge, emulsify and build up acidity. Recent years have seen the introduction into refineries of chemical solvents which produce oils of far greater chemical stability than were available heretofore. From an oil standpoint treatment by these solvents is the greatest forward step since refineries began producing turbine oils.

PURIFICATION OF TURBINE OILS IN SERVICE—That refiners have so materially improved the quality and stability of their turbine oils is no excuse for the general lack of proper facilities for keeping the oil clean while it is in service. Considering the cost and the importance of the turbine to the plant, it is poor business judgment not to provide a filter or centrifuge and settling tank for keeping the oil clean. Twenty-seven years experience with oils and their purification convinces the writer that even if filters or a centrifuge are provided, gravity settling should also be employed. This practice calls for two batches of oil to be used, one in service while the other is settling for two or more weeks. Most of the impurities in a used turbine oil are of almost identical specific gravity to the oil itself; the particles are exceedingly fine, many of them colloidal; and the largest percentage

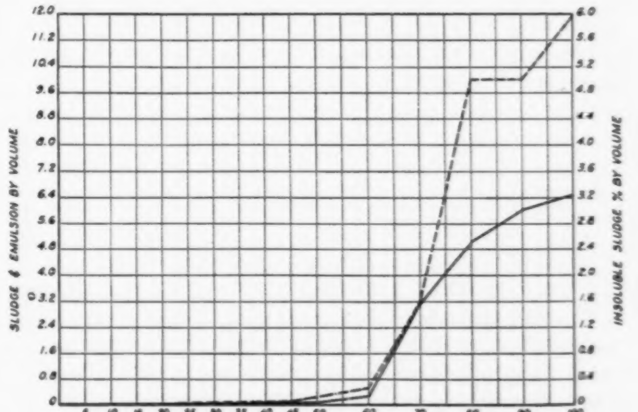


Fig. 3—The chief value of the sludging machine or accelerated life test is that it reveals about when, in service, the soluble and insoluble sludges, and emulsions, will accelerate their formation

of the sludge is soluble in the oil at temperatures about 90 F. To heat the oil higher than this during its cleaning is to fail to remove this soluble sludge. In settling by natural gravity at room temperature there occurs a coagulation and then slow precipitation of these impurities that is most thorough.

Behavior of typical Pennsylvania grade crude paraffin turbine oils of 150 sec Saybolt viscosity at 100 F, Bé gravity 30 to 31, is shown by the data in Table I.

TABLE I—BEHAVIOR OF TYPICAL TURBINE OILS IN ACTUAL SERVICE IN 35,000-KVA STEAM TURBINES

Hours Run	Acidity Mg KOH	Sludge Removed Pounds, Accummulative	Make Up Oil Gallons, Accumulative
	A. OIL (Initial Charge 935 Gal)		
500	0.06	4	40
1000	....	7	...
1500	0.20	10	...
2000	....	14	...
2500	0.24	17	90
3000	....	20	110
3500	0.24	24	...
4000	....	28	150
4500	0.37	34	...
5000	0.40	34	...
	B. OIL (Initial Charge 899 Gal)		
500	0.06	6	...
1000	0.09	13	34
1500	0.12	16	55
2000	0.15	22	110
2500	0.19	28	...
3000	0.21	35	135
3500	0.30	40	155
4000	0.38	42	175
4500	0.43	44	195
5000	0.48	51	210
	C. OIL (Initial Charge 894 Gal)		
500	0.28	..	20
1000	0.36	3	90
1500	0.40	7	141
2000	0.40	13	194
2500	0.40	17	231
3000	0.45	25	255
3500	0.50	30	268
4000	0.53	39	304
4500	0.53	44	344
5000	....	47	350
	D. OIL (Initial Charge 848 Gal *PURE*)		
500	0.10	6	...
1000	0.12	12	...
1500	0.12	16	25
2000	....	18	43
2500	0.14	20	61
3000	0.15	22	86
3300	0.16	24.6	86

WHAT SHOULD BE THE UPPER ACIDITY LIMIT?—At what limit in acidity (mg of KOH per gram of oil) should a turbine oil be taken out of service? There is no general agreement on any one figure. But experience shows that 0.81 should be considered the safe maximum. To go over this may cause a sudden increase in the sludge content if the oil gets a large "shot" of water from excessively leaking shaft glands or other sources. Most of the acid is in the sludge. Through removal of sludge and washing the oil in water then drying it by filtration, centrifuging and settling, the oil is suitable for another long period of service.

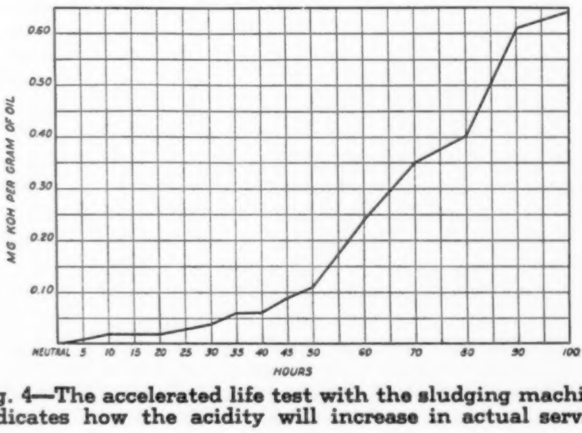


Fig. 4—The accelerated life test with the sludging machine indicates how the acidity will increase in actual service

EFFECT OF GALVANIZED METAL SURFACES—Experience has taught the avoidance of galvanized metal surfaces for filters, piping, screens, etc. The zinc dissolves, chemically combines with constituents in the oil charge and zinc soaps are formed.

Accepted Tests for Turbine Oils

Emulsification: A.S.T.M. D 157–28. Acidity: A.S.T.M. D 188–27T. Demulsibility: Herschel Test. Accelerated Life Test: Funk Sludging Machine. A second choice is the U. S. Navy Work Factor Test.

Tests other than the above, when the gravity, flash, fire, viscosity, color and pour are known, are unnecessary.

The curves (Figs. 1 to 4) show typical cases of what the sludging machine tests reveal as to how oils will behave in service.

PARAFFIN OR NAPHTHENIC BASE—Which is preferable? There is an almost universal preference for turbine oils of 28 to 32 gravity Bé or oil of paraffin base crude origin. Thus inferentially, at least, naphthenic base oils are unsuited. Further use of naphthenic base oils properly refined will likely reveal that this inference has little basis.

NON-INFLAMMABLE TURBINE LUBRICANT—These are being sought, particularly for turbines operating on very high total steam temperature, so high the oil will not ignite if it contacts the hot frame in event of serious leak at the high temperature end bearing. It is, perhaps, too early to report progress with such lubricants as are now being developed.

Edward R. Fish, Chief Engineer, Boiler Division, Hartford Steam Boiler Inspection & Insurance Company, was elected senior vice president of the American Welding Society at its recent Annual Meeting in New York.

C. H. Fellows of the Detroit Edison Company has been chosen chairman of the Executive Committee of the Joint Boiler Feedwater Studies Committee of the A.S.M.E., the American Boiler Manufacturers Association, the Edison Electric Institute, A.S.T.M. and American Water Works Association. He succeeds Sheppard T. Powell who was chairman for several years but who was compelled to resign on May 7 owing to the pressure of work from his private consulting practice.

Dr. Conrad Matchoss, for many years Director of the Verein Deutsche Ingenieure, Germany, and well known to engineers in this country has resigned and will devote his time in the immediate future to preparing a history of engineering.

George Ramsey, whose name is familiar to COMBUSTION readers through his series of articles on patent law, has formed a partnership with F. J. Kent, C. F. Chisholm and R. B. Lutz for the practice of patent trademark and copyright law with offices in the Woolworth Building, New York.

When the Power Load Grows

By A. G. CHRISTIE

General problems connected with the future growth of the power load and means for meeting such an increase were presented in Part I which appeared in the June issue. This section will discuss certain of the plant equipment and will comment upon possible developments in machines.

PART II—Plant Equipment

Shall the new turbines operate at 1800 or 3600 rpm? Single-cylinder turbines at 1800 rpm are available in sizes ranging from 10,000 to 90,000 kw while two-cylinder tandem units with single generators as large as 165,000 kw have been built. Obviously, the superpower station with its large units would require turbines of 1800 rpm.

If more stations of small capacity spread over a system are preferable to a large plant, then more careful consideration must be given to turbines of moderate output and to the relative advantages of the two speeds for such units. Furthermore, many of the smaller plants throughout this country and Canada require equipment of the sizes that may be furnished at either speed.

The largest single-cylinder unit expanding to condenser vacuum and operating at 3600 rpm is a 15,000-kw Parsons turbine which has served for the past five or six years in the municipal plant at Regina, Sask. C. A. Parsons & Co. have offered single-cylinder turbines of 25,000 kw, 3600 rpm for operation at modern pressures and temperatures and at high efficiency to another Canadian plant. Similar units could undoubtedly be furnished by American builders, so that one can consider that single-cylinder, 3600-rpm turbines are available up to 25,000 kw.

The largest American two-cylinder tandem, single-generator units at 3600 rpm are probably the 15,000-kw turbines at the Bremo Station in Virginia. In Great Britain two-cylinder tandem units of 50,000 kw and over at 3000 rpm are in service in many stations while on the continent even larger turbines are operating. It would therefore appear reasonable to expect that two-cylinder tandem turbines at 3600 rpm can be furnished up to about 40,000 kw capacity for high steam pressures.

Why should so much consideration be given to 3600-rpm turbines? The trend in turbine design has, from early days, been toward higher rotative speed and units of smaller dimensions. The first 5000-kw unit operated by the writer, ran at only 750 rpm and even 1500-kw units ran only at 1800 rpm. All such units today would operate at 3600 rpm.

For turbine sizes up to 25,000 kw. single-cylinder units at 3600 rpm will weigh less, take smaller floor space, require less massive foundations and should have somewhat higher efficiency than similar capacity 1800-rpm units. The higher speed unit should also cost less to build after development charges are paid off. It should be equally reliable and available in service.

Two-cylinder units at 3600 rpm will have lighter spindles, casings and generators, will require less massive foundations and should have higher efficiency than similar sizes of turbines at 1800 rpm. The floor space, however, may be somewhat greater for the 3600-rpm units though crane height required will be less than for 1800-rpm single-cylinder turbines of the same capacity. The cost of the two-cylinder construction should be about the same as that of the single-cylinder units of the same capacity at lower speeds. Attention should be directed to the possibilities of the higher speed units although the adoption of this type is a departure from recent practice in this country.

For large capacity units or where space in the turbine room is limited—as for instance, when it is desired to increase the total capacity of a completed or nearly completed plant—then one may give consideration to turbines of the steeple-compound type. Usually the high-pressure cylinder is built for 3600 rpm with an 1800-rpm low-pressure unit. Both can be built for 1800 rpm if desired. The limitations of this type, make it desirable for special installations only, such as where the steam must have intermediate reheating or where space is limited. It is hardly likely to become a standard form for central-station service.

Considerable trouble has been experienced for some years past with erosion of the last blade rows of condensing turbines by water droplets, particularly where high vacuum and high tip speeds prevail. While studies have been made to determine the nature and size of the droplets, there does not appear to be any method available to prevent their occurrence for given steam conditions. Efforts have been made first, to remove as many of these droplets as possible by drainage grooves at each blade row and second, to provide a hard non-erosive metal facing for the blading normally subject to erosion. Several facings such as stellite, chrome alloy steels, etc., have proved effective in prolonging the life of these blades. Some drainage grooves are said to remove about 25 per cent of the moisture present in the steam which substantially improves blade performance. One can expect much better performance in regard to low-pressure blading from new turbines embodying these improvements. As noted in an earlier paragraph, steam conditions are now generally chosen to limit the moisture in the exhaust steam to 10 to 12 per cent, by choosing sufficiently high initial superheat.

It is usual practice to include the generator air cooler

and closed air circuit as part of the standard equipment. Further developments in generator construction may be the employment of hydrogen cooling and of higher voltages in the windings. Hydrogen cooling will enable higher ratings to be obtained from a given generator, or the employment of a smaller and less expensive frame for a given output. However, the difficulties inherent in the use of hydrogen in a generator that must be started and stopped frequently has, up to date, deterred the use of this effective cooling medium.

There has been a steady increase in generator voltages since early days. In this country the highest voltage used, to the writer's knowledge, is 22,000 volts. However, C. A. Parsons & Co. have furnished many generators abroad for 33,000 and 36,000 volts. The operation of these units is said to be quite satisfactory and repeat orders have been received. Such voltage can be used for direct send-out without the employment of transformers and their necessary switches. This tends to simplify and lower station costs. There appears to be no serious obstacle other than patents to the employment of similar voltages on American machines.

Fewer Bleeder Heaters Used

A few years ago, it was common practice to add as many as four bleeder heaters to the main unit to heat the condensate on its way to the boiler. The economies to be secured by such regenerative heating are well known as they have been discussed fully by other writers. However, with increased steam pressures, the boiler proper has been reduced to moderate proportions and considerable area added as economizer surface. Under such conditions, the feedwater may not always require to be as hot as otherwise and in some cases only three bleeder heaters are now used. This problem of the maximum station economy with economic investment in economizer and bleeder heaters requires much study to arrive at the optimum results. Studies made to date to determine this desired ratio have not developed a standard method of solution applicable to all cases.

Some years ago W. Viessman and the writer proposed in a paper before the A.S.M.E. that a system of hot feedwater storage be employed in connection with three- and four-stage bleeding as a means for economically meeting short peak loads on the system. This was a modification of the method used by Dr. Marguere at Mannheim, Germany, though the German system was unknown to the authors when the paper was prepared. Our scheme provided accumulators which were fully charged at the beginning of the peak load with sufficient hot feedwater from the bleeder heaters to meet the full boiler requirements over the peak load period. The plan contemplated about 17.5 per cent over-capacity in the generator, or the Parsons plan of refrigerating the generator cooling air during peak loads to carry 17.5 per cent overload. During the peak load period, all bleeders were to be shut off and the cold condensate run to clean water storage. The effect of shutting off bleeder heaters is to divert all entering steam through subsequent turbine stages to the condenser. The resultant overloading of the low-pressure blading and of the condenser decreases efficiency somewhat but results in an increase of about 17.5 per cent in turbine output. This has been verified by test in central stations.

In the meantime the boiler is fed with hot feed from the accumulator storage so that the change in bleeder service has no effect on feed or on boiler operating conditions. In fact, the steam output and efficiency of the boiler remains constant though the station output is increased 17.5 per cent. Recharging of the accumulator is carried out at night and at other low load periods. Such recharging increases boiler demands at the time when such additional output may favorably affect boiler and furnace efficiency. This increased boiler efficiency partially offsets the extra heat required for recharging. The cost of obtaining this extra capacity of 17.5 per cent, including cost of extra generator capacity, accumulator, pumps, etc., was estimated to be about $25 per kw of added capacity on a 50,000-kw unit, a remarkably low investment for increased plant capacity.

No American plant embodying this system has been installed to date. In a modified form it is employed at Mannheim and elsewhere in Germany. A recent installation with the largest feedwater accumulator in existence has been made at Durban, South Africa. Similar plant with some modifications is now under consideration for several of the largest stations in Great Britain. It wou'd seem that this method of carrying peak loads, with low investment and operating costs, should be given more careful study by American engineers.

Another method may be adopted to increase the output of old stations in which there are turbines without bleeder heaters. A special bleeder turbine can be added with provision to heat all the boiler feedwater to about 80 per cent of the saturated temperature at boiler pressure. No steam enters this turbine other than that needed for such feed heating. No additional heat input is necessary at the boilers except that necessary to overcome the bleeder unit's radiation losses. The power generated by this turbine would be a clear addition to the station's capacity and this increase might amount to as much as 10 per cent. Since no condenser is necessary, this plant could be installed at a low cost per kilowatt of added capacity. Such a type of non-condensing bleeder turbine is installed in several European plants and in at least one American station.

Both closed and contact heaters are used on bleeders. The latter are somewhat more efficient than the average closed heater, as the feedwater is heated to the saturated temperature of the bled steam. Contact heaters require removal pumps at each heater in place of the drainage devices used on closed heaters.

The third and fourth bleeder heaters are frequently supplied with steam which has considerable superheat If the section of a closed heater into which this steam enters is also the section through which the feedwater flows just before leaving the heater, advantage may be taken of the superheat in the entering steam by means of a baffle on the steam side and counterflow of steam and water to heat the feedwater to a higher temperature than in ordinary heaters. The usual terminal difference may be partially or wholly overcome. In the latter case, the closed heater has all the thermal advantages of a direct contact heater.

Evaporators now form a part of the feed-heating system of many condensing stations. These are generally placed in the bleeder system so that they operate between bleeder points at or about atmospheric pressure. The evaporator-condenser serves as a stage of the feed-heating system. Great care must be exercised to see

that no moisture is carried over with the steam from evaporators as this may have serious effects in high pressure boilers. Effective separating and steam washing devices, careful control of evaporator concentration and pre-treatment of water to the evaporator may be required to secure the desired delivery of clean steam.

It was formerly thought that evaporators were justified only in large stations. However, these are relatively as effective and economical in smaller stations and their use is rapidly extending. The presence of an evaporator in a plant stimulates the operating force to decrease leakage, and other losses in order to conserve make-up.

Deaeration of feedwater is necessary particularly where evaporated make-up is used as otherwise serious corrosion may take place in piping, boilers and turbines. For some time it was thought that the condenser, particularly where the condensate was heated to a temperature corresponding to the vacuum, would deaerate water sufficiently for boiler purposes. This is no longer considered sufficient by many engineers, and generally one of the bleeder heaters serves as a deaerator.

Some fires have occurred in stations due to a rupture of the oiling system and ignition of the lubricating oil on coming in contact with piping carrying high superheat. These fires have led to improved designs of oil piping, to better location of oil storage tanks and reservoirs and in some cases to the use of a non-inflammable fluid for speed-control purposes. Research still continues in the search for a non-inflammable lubricant and some new materials are under trial.

Condensers and Their Auxiliaries

Increased steam pressures and temperatures, improved turbine efficiencies and better condenser design, have decreased the necessary condenser cooling surfaces as compared to earlier practice. Single-pass condensers are generally used where water supplies are ample at low head. Tube failures still account for most of the condenser maintenance. The practice of using bowed tubes to care for expansion with both ends rolled into tube sheets, has led to improved performance and the employment of this system is increasing. Welded steel shells are becoming common practice. European builders offer condensers with wrought-iron tubes and tube sheets for fresh water conditions though, to the writer's knowledge, these low cost condensers have never been used in this country. Much still remains to be learned of the proper method of admitting circulating water to water boxes, and of the best spacing of tubes and optimum steam velocities for minimum steam pressure drop and maximum heat transfer. Almost all condensers embody schemes for reheating the condensate to the saturated temperature of the exhaust steam. Some forms of condenser even heat the condensate to a higher temperature. Where circulating waters are such as to encourage algae or slime growths in the tubes, chlorination is employed with economical results.

Deaerated boiler feedwater has decreased air pump requirements. Attention, however, must be given to circulating water tunnels, pumps and piping, with the object of reducing the power supply to the motors to the lowest possible amount. Propeller and other new pump designs are being tried to reduce power and space requirements. This auxiliary power requirement is a steady drain on the station output. Its importance as a factor in station economy has been occasionally overlooked and circulating water layouts have not embodied the best or most economical features possible.

The Boiler Plant

Great advances have been made in recent years in boiler pressures and steam temperatures. Benson boilers are in operation in Europe at the critical pressure of water, i.e., 3260 lb per sq in. Once-through experimental boilers in this country have been tested at pressures of 4000 lb per sq in. A turbine of 10,000 kw has operated for over two years in the Delray Station of Detroit Edison Co. at a steam temperature of 1000 F. One can therefore say that as far as boilers are concerned, the present practical limits of pressure and temperature are about 3500 lb per sq in. and 1000 F.

There is no part of the power station in which greater or more radical changes may be expected in the next few years than in the design of boiler plant. In past years, one chose between the conventional bent-tube boiler or the straight-tube boiler of sectional or box header type. While these forms are still widely used, they have been greatly modified in many cases from earlier designs and besides a great number of new types have been placed on the market. Among these are the Benson, the Loeffler, the Sulzer Monotube, the Velox, the LaMont, the Atmos and the Wagner-Bauer. None of these except the Benson are at present available on the American market[1] but all are in operation abroad in experimental and commercial units. When new plants are built, it is possible that the more successful of these foreign types may be introduced in America.

Changes in boiler design are due principally to five influences: welding, higher steam pressures, proper metals, better superheat control and improved boiler feedwater. Certain types would be impossible to construct if welding were undeveloped as, for instance, the Sulzer Monotube. Welding is now used extensively on all types. Its use for drum construction eliminates the troublesome riveted joints which are subject to caustic embrittlement. Improved technique in welding and means for testing welds by X-rays now give purchasers assurance of safe welded boiler drums which, in general, should be less expensive for high pressures than the heavy riveted constructions or hollow forgings. The use of welds eliminates many joints at which leaks may occur and, hence, improves operating reliability.

Circulation problems become more serious with increased steam pressures. Hence, some designers have turned to forced circulation as in the Benson, LaMont, Velox and Sulzer boilers and to radically new designs as in the Atmos boiler. Even the bent-tube type has been modified to improve circulation. Recent straight-tube sectional-header boilers installed in this country have had the drums placed at considerable height above the tube banks to achieve the same purpose, the intervening space being utilized for the superheater and economizer. This construction is embodied in the boilers of the new Buzzard's Point Station, Washington, D. C. Circulation in a boiler depends upon the difference of weight of a column of water and a column consisting of a mixture of water and steam bubbles. The decreased

[1] The Benson boiler patents in this country are now controlled by the Westinghouse interests who expect shortly to make a commercial installation.

specific volume of high-pressure steam decreases the size of the steam bubbles in this mixture and at the same time increases their weight. With the same rate of evaporation and same drum height above the tubes, there is less circulating head with high pressures than with low pressures; hence, the trend toward forced circulations in some new designs. Some recent marine and other boilers are being provided with recirculating tubes outside the path of the gases, to accelerate circulation in the steaming sections.

Little need be said of the influence of improved metals on boiler construction. Special alloys are available for the highest steam temperatures now in use. The Loeffler boiler, in which practically all heat is absorbed by superheater tubes, is an example of a type where construction has been made possible by improved metals. When still higher temperatures are attempted, new alloys will have to be developed for such services. Aside from these special alloys, there has been real progress in the production of better steels for ordinary boiler use and particularly of improved tube materials. Better rolling-mill technique, less inclusions, sounder ingots and control of ingredients, have all contributed to this improvement.

A difficulty with early convection superheaters was the wide fluctuation of steam temperature with boiler rating. Radiant superheaters produced a different characteristic performance to the convection; that is, the steam temperature decreased with increased output. In recent designs the superheater surface has been partly radiant and partly convection, resulting in a more constant superheat at different ratings. In some recent boilers the superheater has been built in two sections and regulation of superheat obtained by a desuperheater between sections. In another design the flow of gases past the two sections is so controlled as to give constant superheat at all boiler ratings. This constant superheat temperature leads to better economy in the turbine at varying load and thus to better overall station efficiency. It further lessens temperature changes in piping and turbine casings.

Boilers for high pressures, and consequently higher boiling and tube temperatures, must be furnished with feedwater free from scale-forming and oxidizing impurities. Scale on such heating surfaces would soon cause the tube to overheat and burn out. It is well known that chemical reactions increase in speed as the temperature is raised so that corrosion is very rapid when any oxidizing impurities exist in the boiler feedwater at high pressures. These considerations have led to careful studies of boiler feedwater conditioning and treatment and to the control of these conditions in so far as possible. Much can still be learned of the chemical reactions in a boiler under high pressure and of the effect of certain substances added to control the pH value of the water, of its alkalinity and of its corrosive and embrittling properties. There is a marked tendency to require higher pH values in the boiler than formerly. Some other substance than sodium sulphate is desirable to control embrittlement and lessen blow-down. The present sulphate-alkalinity ratios necessitate frequent blow-down which increases the necessary make-up water. Boiler feedwater treatment and control is by no means a settled procedure and much research must still be devoted to this subject.

Some unique boiler designs have been developed to overcome feedwater troubles. For instance, the Loeffler boiler utilizes superheat surfaces through which the saturated steam from the drum is forced by a pump, and which absorb the heat from the fuel. Part of this steam goes to a turbine. The remainder of this highly superheated steam is bubbled through boiler water in a drum placed outside of the side of the furnace and completely out of contact with flue gases. The heat of superheat serves to evaporate the water in this drum. It is claimed that less attention need be given to the character of feedwater with such construction, as no heating surfaces have scale deposits. A plant in Czecho-Slovakia is operating with several Loeffler boilers at 1900 lb per sq in. pressure.

In the once-through boilers of the Benson or similar type, which operate at or about the critical steam pressure, another difficulty occurs at that point in the tubing where the water changes to steam. Since these boilers have no steam drum, any soluble salts in the feed must either be deposited on the tube surface at the point where steam is formed, or must be carried along as dust in the steam to be deposited later on the turbine blading. Such blade deposits have proved troublesome even at the moderate pressures now in use as they obstruct the flow of steam and materially reduce turbine capacity. This has made it necessary to develop a technique for washing the blades periodically with wet steam to dissolve the deposits which are largely sodium salts, and to carry them to the condenser. There have also been developed means in standard boilers for washing the saturated steam with entering feedwater before the steam leaves the boiler drum and enters the superheater, but this cannot be done on a once-through boiler. In the Benson boiler these salts deposit on the tube surfaces in the evaporation zone. To prevent the tubes from burning out, this section of tubing is now placed out of contact with the hot gases and means are provided for blowing each tube periodically to dissolve these deposits and to remove them from the boiler.

Deaeration of feedwater has already been mentioned. In some cases of high boiler pressure, it has been thought that deaerators do not remove all oxygen under all turbine load conditions. Consequently sodium sulphite is added to the feedwater to remove the last traces of oxygen. When this substance combines with oxygen, sodium sulphate is formed which increases the sulphate-alkalinity ratio of the boiler and has no undesirable effect upon boiler operation.

Probably all new boilers will have a considerable proportion of the evaporating surfaces disposed to form water walls about the furnace proper. This eliminates much refractories, lessens maintenance costs of furnaces and permits greater rates of fuel burning with higher furnace temperatures and consequently better rates of heat transfer. Water walls receive the greater proportion of the heat as radiant heat at high rates of absorption. Evaporation is consequently very rapid in such tubes. Hence, it is necessary to give careful consideration to water circulation in such tubes. Large down-comers, ample separating headers at the top, recirculating tubes, and adequate distribution of water to all water wall tubes are factors in satisfactory construction and operation.

Many forms of water-cooled walls are now available

and under development. Further experience with all types is necessary before any one form can be said to be superior to the others.

Boiler development has followed two lines. Some boilers approach the flash type in which there is small water capacity but an ability to respond rapidly to changes in the rate of fuel burning. There are cases where such changes in heat supply cannot be made instantaneously as, for instance, under a hot banked boiler subject to a sudden demand when interconnected hydro service fails. A type of boiler with an extra large drum has been developed for this service and has given excellent satisfaction. The large volume of hot water in the drum acts as in a steam accumulator and on sudden demand delivers large quantities of steam as the pressure falls while the fires in the furnace are being conditioned. Such a boiler may carry the full capacity of its turbine for several minutes in an emergency.

The Velox boiler built by Brown Boveri & Co. embodies a new design principle. Fuel oil or gas is burned under a pressure of about 20 lb per sq in. in a furnace enclosed within the boiler. The resultant gases of combustion escape past the steam generating and superheating tubes at quite high velocity and with high coefficients of heat transfer. The flue gases which are under pressure operate a gas turbine which in turn drives the compressor that delivers the air supply to the furnace. This design results in a small compact plant, responsive to sudden load demands and, according to tests, capable of operating at high boiler and furnace efficiency over a wide range of load.

The evaporating capacity of a given boiler is, in general, dependent upon the amount of fuel that can be burned in its furnace and the capacity of the devices provided for the removal of the flue gases. This upsets the idea that a given amount of heating surface has, in itself, a given steaming capacity. High rates of steaming prevail in many recent boilers. Capacity of the furnace is therefore the factor that fixes boiler output. Hence, great attention should be devoted to problems of furnace design in new units, and in reconstructed old plants.

Furnace Capacity Fixes Output

Combustion in furnaces has been rated in terms of Btu heat release per cubic foot of furnace volume. The early pulverized coal furnaces were provided with refractory walls and had low rates of heat release. Water-cooled walls and slag-bottoms in furnaces have enabled these rates to be increased to about 35,000 Btu per cu ft in conservative designs. Heat release is dependent partly upon burner design and partly on means for supplying secondary air. Turbulence under high temperature conditions appears to be the best means of securing rapid combustion in limited furnace volumes. Since it is desirable to maintain boiler house volumes at a minimum, the tendency in new plants will be to design for high rates of combustion and smaller furnaces.

Where oil serves as fuel, much higher rates of heat release are obtainable than with powdered coal. Jones and Solberg in a recent paper on "Marine and Naval Boilers" (*Soc. of Nav. Arch. & Mar. Eng.*) state that heat release at the rate of 200,000 Btu per cu ft is by no means unusual on shipboard. It might also be pointed out that few furnaces on shipboard are provided with water-cooled walls. The above rate is the more remarkable on that account. Goos (*The Engineer*, Mar. 22, 1935) states that heat release at the rate of 340,000 Btu per cu ft can be generated in the Benson boiler and of this 260,000 Btu can be absorbed as radiant heat. These figures exceed current land practice. Such rates might be adopted for peak load service on land and would obviously lead to smaller and less expensive furnaces. A combination of oil burners for use at peak load combined with stokers or pulverized coal equipment might be an economical solution of this problem.

With regard to fuels, pulverized and stoker-fired coal, oil and gas will all be used in new stations. Development is still in progress with pulverized coal burners and good burners are now available. Pulverizing equipment is becoming standardized in several types, with mill-drying almost universal. In some cases flue gases rather than preheated air are used for mill-drying, thereby effecting a small thermal advantage. Opinions still differ as to the relative merits of bin and storage versus direct firing for powdered coal. Each has certain advantages according to local conditions. The trend, however, judging from a majority of the later installations, appears to be toward direct firing in many of the newer plants, although the storage system has been extended in a number of plants in which it was originally installed.

Any degree of air preheat may be used with pulverized coal. The limit will be fixed by the temperature of available flue gases and the ability of the air preheaters to stand the prevailing temperatures. Primary air temperatures to the burners must be maintained below that point at which the conveyed coal softens and becomes plastic.

Fly ash troubles have been largely diminished by modifications of the first rows of boiler tubes to form the so-called slag screens. In general these consist of widely spaced tubes placed in front of the regular tube banks. These tubes by absorbing radiant heat from passing incandescent ash particles, cool these particles so fast that they are solidified when contact with the standard tube bank is reached. Solidified particles do not adhere to form slag on the tubes as semi-fluid particles would do. Old boilers which could only be operated at limited ratings on account of slagging of the tubes above stokers, have had the lower rows of tubes modified and other slag-screen tubes added below the original first row. Their steaming capacity has thus been greatly increased and operating troubles lessened.

The early side wall troubles from ash adherence to refractories have been largely overcome by the use of water walls. Early installations of pulverized coal furnaces were almost all provided with dry bottoms in which the ash sometimes formed large clinkers when the furnace operated at high ratings. This trouble was effectively overcome by the introduction of the water-cooled slag screen which permitted the ash to sift through in a dry powdery state except in some instances where the flame impinged directly down on the screen, in which case some slagging resulted. The introduction of the slag-bottom furnaces was a somewhat later development. The early troubles with maintenance of these slag-bottoms now appear to be largely overcome by the use of water-cooling tubes to support a hearth consisting

largely of granulated ash. Slag bottom furnaces are particularly suited to coals with low fusing ash. Coals with high fusing ash require furnace operation at high ratings and high temperature to make the ash sufficiently fluid for easy tapping. Fluxing materials may be developed later to increase ash fluidity without eroding the hearth lining and bottom. The granulated slag from these furnaces is much more easily disposed of than the loose dust from dry-bottom furnaces. Present practice includes both the dry-bottom furnace with slag screen and the slagging furnace, depending on local conditions and fuel.

Slag bottom furnaces induce more rapid combustion of fuel due to the heat radiated from the hot slag. Any large coal or coke particles that settle to the bottom of the furnace float upon this slag until burned, instead of going into the ash as in dry-bottom installations. Tapping need only be done infrequently and if the ash is fluid, is neither a laborious nor expensive method of removal. However, if the coal contains much pyrites, the resultant heavy iron compounds that may form in the ash may increase tapping difficulties. It has been suggested that such slags might be treated with carburizing and other materials to cause it to form cast iron but the large sulphur content mitigates against the success of this scheme.

Utilization of Slag Still a Problem

In Sweden the slag discharged from charcoal iron blast furnaces is cast into blocks which are used for building and other walls. These blocks are hard, enduring, and do not spall with temperature changes. Slag from American boiler furnaces, due to sulphur or other impurities, does not, according to reports, form a lasting block. Chemical studies may later show how, by fluxing, suitable blocks could be formed. This would provide an economic outlet for this waste material.

The improvements in underfeed stoker construction and operation during the last few years have been quite phenomenal. The use of forced draft, zoned air control and improved extension grates and ash pits are leading elements in these advances. Much remains to be done in further development of these new devices. There are many places where such stokers are preferable to pulverized coal equipment. Automatic control of the forced blast enables these new stokers to carry rapidly varying loads with ease at high efficiency. The clinker from such stokers may have a sales value for the manufacture of cinder blocks when building construction is renewed.

Many coals such as the lignites have high grindability factors and hence have not been widely burned as pulverized fuel. Lignite and those coals of low volatile contents such as anthracite and coke dust can be burned advantageously on traveling grate stokers. Many new types of stokers for small boilers have been developed in recent years.

Furnace operation with stokers has been greatly improved by the use of water walls about the furnace and slag screens on the boilers. Auxiliary power requirements are considerably less with stokers than with powdered coal. Maintenance of the stoker parts has been decreased by improved designs as a result of better understanding of the air cooling of the various parts. It has been suggested that the water-cooling of the more vulnerable stoker parts may prove most important.

Preheated air is widely used with stokers. While higher temperatures have been employed, it seems to be generally accepted that air temperatures of 300 to 350 F are the most suitable.

Oil and gas firing is a relatively simple matter. No ash need be considered. Soot blowers are unnecessary and control is much more simple.

Many of the larger stations are fitted with automatic control of boiler firing. These devices have given good service and they will probably be installed in the larger base load plants. While less expensive combustion equipment is being developed for small boilers, most small plants must still rely on manual operation which is greatly aided by the many excellent instruments now available.

Reference was made in an earlier paragraph to the use of economizers with higher boiler pressures. The flue gases leave these boilers frequently at too high temperatures to be utilized in air preheaters alone, particularly if the air preheat is limited as in the case of stokers. Hence, the economizer serves to recover a portion of this heat. Steaming economizers in which steam may be generated at high boiler ratings are sometimes favored and these virtually serve as counterflow extensions of the boiler surfaces. When hot feedwater from bleeder heaters on the turbine is supplied to an economizer, the problems of dust deposit and its removal are not serious as no condensation occurs. This dust removal can usually be effected by soot-blowers.

The various types of air preheaters have their advocates. No one type seems to dominate the field. The air preheater is subject to certain operating difficulties with some fuels. In cold climates unless the entering air is tempered, condensation of moisture from the flue gases on the cold plates will lead to early corrosion. Tempering of this air requires the recirculation of a portion of the preheated air and thereby increases auxiliary power requirements. In some cases the fly ash in the flue gases has cementing properties when dampened by condensation as in starting-up periods and this results in plugged-up gas passages very difficult to clean. Care must be taken that air and gases circulate freely over all surfaces. Otherwise condensation may occur in cool dead spots with resultant corrosion difficulties.

Where flue gases must be washed, it has been suggested that these be cooled to the necessary temperatures by forms of air coolers. Since the desired gas temperature is below the dew-point of the gases, this cooling will present difficult problems. The use of stainless steel has been suggested but this will not prevent cementing of the ash previously mentioned. No attempt at such heat recovery has been made up to the present so that much development remains to be done.

Coal and Ash Handling

Coal handling is an individual problem at each power station. Many types of coal handling equipment are in satisfactory use depending upon whether the coal is rail or water borne, the amount and character of outside storage, and the bunkers provided inside the power plant. Attention is drawn by the necessity of low plant investment to storage outside the power plant in place of inside bunkers which involve heavy and expensive steel construction. This outside storage has taken the form of concrete silos, of open bunkers at ground level,

and of roofed-over outside storage. All of these methods can be satisfactorily employed in certain climates. The very low temperatures of our northwest and of Canada in winter make out-door storage out of question as severe freezing has been experienced when temperatures moderate.

Sluicing of ash and granulated slag is common practice for ash removal in pulverized coal plants and is frequently used for the more bulky refuse from stokers. This material is removed from the settling basin by some form of grab-bucket. Such ash handling takes little labor and also provides comparatively clean basements.

Piping

Piping and valves have been developed for higher pressures and are under trial for higher steam temperatures. Alloy steels are used extensively in these services. In order to keep down first costs and to reduce expansion to a minimum, the relative position of turbines and boilers should be studied to bring them as close together as possible. Departures from present practice in these relative positions may be justified by the advantages gained in shorter piping. Corrugated and creased bend piping have been advocated for steam piping. New data upon the performance of such piping will shortly be available from research under the joint auspices of the U. S. Navy and the Johns Hopkins University.

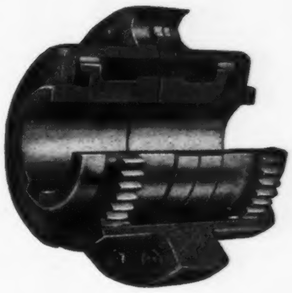
Ventilation Problems

In northern latitudes heating of certain portions of the power plant is necessary in cold weather. Trouble is also experienced in some stations with sweating of the steel work of the roof. In still other plants fogs occur in the boiler house where cold coal is stored in overhead bunkers. Many of these difficulties can be overcome by a proper system of ventilation. A recent plant design of the writer's provided for the distribution of hot air from the air preheater to portions of the turbine and boiler room and the removal of equivalent moisture-laden air from these rooms by the forced-draft fan. This arrangement prevents the occurrence of high humidity inside the plant by the rapid removal of any moisture present. Ample heating is provided at the same time as satisfactory ventilation. Similar schemes might be tried in some of the older stations where sweating and fog are unmitigated nuisances in winter.

Electrical Plant

Formerly all electrical equipment was housed inside the power house. This naturally increased plant cost. Now switches, transformers and other necessary equipment can be satisfactorily placed in outdoor locations. This type of installation is widely used in Canada under severe winter conditions so that no hesitation should be shown to its use in this country. Instrument leads and relay controls may be centered in a small operating room inside the power plant. This out-door arrangement while requiring more land, will result in a lower building cost.

Many important elements of the power plant have not been discussed in the preceding paragraphs and the comments in this paper may not meet the views of all engineers. By giving consideration to the questions discussed, those reponsible for the design of new plants will be prepared to proceed with assurance on their problems "When the Power Load Grows."



ALLOY STEELS for Temperatures over 800 F in Boiler Drums, Superheaters and Steam Piping*

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A review of the physical properties of the principal alloy steels suitable for high-temperature, high-pressure steam service together with a brief explanation of the function of various alloying elements in meeting creep, satisfying tensile and fatigue requirements, impact, corrosion and oxidation at elevated temperatures.

A LARGE part of the improved fuel economy of modern steam generating plants is due to the use of higher steam pressures and temperatures. At present the optimum steam pressure and temperature for greatest overall economy has not been determined. Until about five or six years ago, 750 F was considered the practical upper temperature limit for superheated steam. This involved some problems that were not encountered when working at lower temperatures, but these problems have for the most part been satisfactorily solved. Since that time a number of stations operating at temperatures of 825 to 850 F, and at least one unit operating at a temperature of 1000 to 1100 F, have been built in this country. Just how much higher these temperatures can economically go depends on the ability of the metallurgist to develop suitable steels.

As long as temperatures did not exceed approximately 750 F the plain carbon steels were satisfactory, at least as regards the necessary strength at the temperature used, and they can probably be used with a reasonable degree of success for temperatures as high as 900 F. However, they do not possess those properties required for satisfactory operation for long periods at high temperatures and it is necessary to use alloy steels in such applications.

Until a relatively few years ago a knowledge of the physical properties of a steel determined at room temperatures was considered all that was necessary for the proper design of a piece of apparatus, regardless of the temperature at which it was to be operated. In some cases where the apparatus was to operate at a somewhat higher temperature than customary the physical properties determined at the operating temperature were used as a basis for design. Today other factors must be taken into account, one of the most important of which is the so-called limiting creep stress, or as some prefer to call it, the creep strength.

Creep strength is a subject that is being widely discussed by designers of pressure apparatus that must operate at elevated temperatures. There is as yet no general agreement as to the best method of determining creep strength, nor as to the weight that should be given to creep strength determinations in the design of high-temperature pressure apparatus, but engineers and designers are agreed that it must be taken into consideration.

The terms "creep," "creep strength" and "limiting creep stress," as applied to steel, are relatively new and it might be well to describe briefly just what they mean. When a piece of steel is subjected to a stress it is strained or deformed. If the stress is applied at room temperature and does not exceed the elastic or proportional limit, strain or deformation is proportional to the applied stress and is apparently entirely independent of time. When the stress is removed the piece of steel returns to its original size, that is, it behaves for all practical purposes as though it were a perfectly elastic body.

At elevated temperatures the behavior is somewhat different. Even relatively low stresses will result in a deformation that increases with the length of time the stress is applied. When the stress is removed the piece of steel does not return to its original size but has been permanently deformed. This is the phenomenon now generally known as creep. It may thus be defined as the permanent elongation or plastic flow that occurs in a metal which is subjected to a stress and which increases with the time of application of the stress.

The ability of a metal to withstand creep is designated as limiting creep stress or creep strength. It is usually expressed as the maximum stress which will cause a plastic flow or permanent deformation not exceeding

* A paper presented at the Annual Meeting of the National Board of Boiler and Pressure Vessel Inspectors, Chicago, May 14 to 17, 1935.

a certain amount in a specified number of hours at a definite temperature. It is frequently expressed as the stress which will cause a permanent elongation of not more than one per cent in 10,000 hr at any particular temperature. For the design of some equipment, it seems desirable to express it in terms of one per cent in 100,000 hr and this figure is favored by those desiring to be conservative. In many applications the creep strength is of minor importance but in pressure vessels operating at high temperatures it becomes of extreme importance and in many cases it is the factor which determines the design of the apparatus.

Other Important Properties

While creep strength is of the greatest importance, a material to be satisfactory for service at elevated temperatures must have other suitable properties. It must possess satisfactory tensile and fatigue properties and impact strength and must be capable of withstanding corrosion and oxidation at the temperature at which it will be used. It must be capable of being fabricated into the required apparatus at a reasonable cost and it must not deteriorate structurally when exposed for a long time to the given operating conditions.

The relative importance of these factors varies with the individual installations. In some installations a relatively low cost steel with good fabricating properties might be chosen even though its high temperature strength were only nominal, while in another installation the steel with the greatest strength or resistance to oxidation, as the case may be, might be the proper choice even though its cost were several times as great.

Modern metallurgy has kept pace with power plant design and is prepared to furnish the materials required for the economical construction and operation of these new high-pressure, high-temperature installations. As in so many other modern engineering developments, the answer is—alloy steels.

Alloy steels suitable for high temperature uses were developed largely to satisfy the needs of the oil refining industry that resulted from the growth in the use of the cracking process for the production of gasoline. Oil cracking equipment, particularly tubes, has a relatively short service life due to corrosion, oxidation and creep. These are the very same factors that are of the greatest importance in high-pressure, high-temperature steam equipment and it is not at all surprising that the same steels found satisfactory in the oil industry should also find application in the steam power field.

Most Suitable Alloying Elements

Before going into details regarding the various steels that have been found satisfactory for this class of service in actual operating tests, or those that give every promise of being suitable for this class of work, it might be well to review briefly the effects of the alloying elements that have proved most useful in giving the desired properties.

The alloying elements found most useful for steels suitable for high-temperature, high-pressure steam equipment are chromium, molybdenum, tungsten, vanadium, manganese, silicon and nickel. The use of titanium, columbium and nitrogen in high chromium steels is the subject of experimental work at the present time and indications are that steels containing these elements will find extensive use in high-temperature, high-pressure equipment. Each of these elements exerts very definite influences on the steel to which it is added, but the effect of each is modified by the presence of other elements and it thus becomes of the greatest importance to obtain a proper relation between the amounts of the varying alloying elements in order to obtain the best results. Alloy steels in which the proportions of the various elements have been chosen so as to give the best possible combination of the required physical and chemical properties are now known as balanced alloy steels.

Chromium is present in practically all steels designed to be used at high temperatures. It increases strength, hardness, oxidation and corrosion resistance and creep strength. For extreme resistance to corrosion and oxidation at high temperatures a large percentage of chromium is absolutely essential. All of the so-called stainless or corrosion resistant steels contain high percentages of chromium, usually in excess of 12 per cent and occasionally more than 30 per cent. Chromium, when present in certain percentages, may cause undesirable air-hardening properties, and titanium or columbium is added to overcome these and at the same time retain, and even improve, the corrosion and oxidation resistance of these steels. Certain of the high-chromium steels exhibit a coarse grain structure which adversely affects their hot working qualities and physical properties. It has been found that nitrogen is effective in refining the grain and improving the physical properties of these steels.

Molybdenum when added alone to a plain carbon steel is probably the most effective of the elements in improving the creep strength. When added to the chromium steels, such as, for instance, those containing about 4 to 6 per cent of chromium, it likewise acts to increase somewhat the creep strength and probably has a slightly favorable effect on corrosion resistance. It is also effective in increasing the corrosion resistance of some of the high chromium-nickel steels, such as the stainless steel commonly known as "eighteen–eight."

Tungsten acts very much like molybdenum in steels suitable for high-pressure, high-temperature equipment. Because of the fact that in the 4 to 6 per cent chromium steels about twice as much tungsten as molybdenum is required to obtain a certain effect, molybdenum is generally favored over tungsten for these steels, largely as a matter of cost. However, in steels of other compositions tungsten is apparently fully as effective as molybdenum and may even have certain advantages.

Vanadium increases creep strength and is particularly effective in producing a fine grain structure and in increasing the impact strength and fatigue values. It also improves the welding qualities of some of the low alloy steels.

Nickel when present in relatively small amounts is effective mainly in giving increased strength and toughness. It is the element most commonly used to produce the so-called high-chromium austenitic steels which have properties that differ essentially from those of the usual alloy steels. The austenitic steels containing, for example, approximately 18 per cent chromium and 8 per cent nickel are non-magnetic and cannot be hardened by heat treating. They are extremely resistant to many corrosive substances and oxidation at high temperatures; moreover, they can be cold worked so as to exhibit very

high physical properties and yet retain sufficient ductility to enable them to be readily fabricated while cold.

Manganese is usually added to increase strength and in some cases to give improved hot working properties. Silicon likewise results in added strength and in increased resistance to scaling at high temperature.

Frequently, after the maximum benefit that can be obtained from the addition of one of the alloying elements has been reached, a further improvement can be obtained by the addition of one or more other elements. This is, at least in part, an explanation why some of the more or less complex alloy steels have been developed.

It is not the intention to go into great detail in this paper regarding the physical properties of the various steels that have been used or proposed for high-temperature steam equipment but rather to indicate, in a general way, in just what manner and to what extent the necessary physical and chemical properties of steels have been improved in order to make them suitable for this type of service. Some of these steels have been approved by the various committees of the national engineering societies and other bodies regulating the use of materials in pressure vessels, tentative specifications have been drawn for others but not yet officially adopted, while others are still in the development stage but give every promise of proving satisfactory.

Properties of Principal Alloy Steels

Chromium-Nickel (18 Per Cent Chromium 8 Per Cent Nickel)

Of the commercial steels now available, that containing approximately 18 per cent chromium and 8 per cent nickel has probably the best combination of properties making it suitable for the most severe high-pressure, high-temperature service. The chemical composition of this steel varies somewhat with the use to which it is to be put. In general, it contains from 17 to 20 per cent chromium, 7 to 10 per cent nickel and under 0.25 per cent carbon. In order to prevent the embrittlement to which it is subject when exposed to corrosive action at temperatures from 900 to 1500 F, titanium or columbium is frequently added in order to "stabilize" and make it practically immune to such action. Molybdenum is sometimes added to obtain increased resistance to the corrosive action of some chemicals, and tungsten and silicon for improved high-temperature properties. This steel is extremely resistant to corrosion and oxidation and has, relative to plain carbon steel or the low-alloy steels, a very high creep strength. It will, for example, resist scaling indefinitely at a temperature as high as 1700 F and has the following approximate creep strength for a creep of one per cent in 100,000 hr as compared with carbon steel.

Temperature	18-8 Steel	Carbon Steel
1000 F	15,000 lb	2700 lb
1100 F	8,200 lb	840 lb
1200 F	5,300 lb	290 lb
1300 F	3,400 lb	....

Piping made of steel of this type has been in use for several years in a high-pressure steam installation operating at a temperature as high as 1100 F and has given entirely satisfactory service. This high alloy steel is, however, relatively expensive and cheaper low-alloy steels having good high temperature properties will probably be more generally used for some time to come.

High Chromium-Tungsten Steel

A steel containing 12 to 16 per cent chromium and 2.5 to 3 per cent tungsten also possesses properties which should make it excellent for high-temperature steam service. Because of its high chromium content, it shows excellent resistance to scaling at high temperatures, has good resistance to corrosion and possesses good creep strength.

4 to 6 Per Cent Chromium Steel with Molybdenum or Tungsten

A relatively low-alloy steel, one containing about 4 to 6 per cent chromium and usually either 1 per cent tungsten or 0.5 per cent molybdenum, has found extensive use in the oil cracking industry and should prove an excellent steel for superheater tubes in high-temperature steam installations. This steel has a creep strength approximately double that of plain carbon steel at a temperature of 1000 F and, in addition, is much more resistant to scaling and corrosion than plain carbon steel at temperatures up to at least as high as 1200 F. It has been used for a variety of equipment operating at high temperatures, particularly in tubes and valves, and has given excellent service. The air hardening characteristics of this steel can be entirely eliminated by the addition of titanium or columbium and this will no doubt greatly increase its field of usefulness.

Steels of still lower alloy content have high temperature properties making them entirely suitable for use in high-temperature steam equipment. Among these are a number of molybdenum steels, including chromium-molybdenum, manganese-molybdenum, nickel-molybdenum and carbon-molybdenum.

Chromium-Molybdenum Steel

A chromium-molybdenum steel containing 0.15 per cent carbon, 1 to 1.5 per cent chromium, about 0.5 per cent molybdenum and 1 per cent silicon, possesses a creep strength of 15,000 lb per sq in. for a creep of 1 per cent in 100,000 hr at 1000 F, which compares very favorably with that of the high-alloy 18 per cent chromium, 8 per cent nickel steel mentioned above. Its resistance to oxidation is not high but is substantially better than that of plain carbon steel. At 1000 F it is about equal to that of the 4 to 6 per cent chromium steel containing molybdenum; at higher temperature it is comparatively somewhat lower.

Carbon-Molybdenum Steel

Another of the low-alloy steels which possesses good high temperature physical properties is a carbon-molybdenum steel containing approximately 0.1 to 0.2 per cent carbon and 0.45 to 0.65 per cent molybdenum. At 1000 F this steel exhibits a creep strength several times that of plain carbon steel. At 1200 F it is approximately twice that of plain carbon steel. Its resistance to corrosion and oxidation at high temperatures is approximately the same as that of plain carbon steel and it can therefore be used to advantage only when these conditions are not severe.

Manganese-Molybdenum Steel

A manganese-molybdenum steel containing approximately 1.25 per cent manganese and 0.25 per cent molybdenum possesses an exceptionally high creep

strength at temperatures up to about 900 F and an excellent creep strength at even higher temperatures. Its resistance to corrosion and scaling is about the same as that of plain carbon steel. It has been recommended for steam piping operating at temperatures not to exceed 1000 F.

Chromium-Aluminum Steel

In Germany a chromium-aluminum steel, the composition of which varies quite widely with the service to which it is to be put, seems to be giving excellent service in superheater tubes. Such tubes are reported to be giving entirely satisfactory service at steam temperatures of 900 to 1000 F and pressures of 15,000 lb per sq in.

Chromium-Manganese-Silicon Steel

An alloy steel not especially designed for high-temperature service but which nevertheless has excellent properties at moderately high temperatures is one containing approximately 0.4 to 0.6 per cent chromium, 1.1 to 1.4 per cent manganese and 0.6 to 0.9 per cent silicon. This steel has been approved by the Boiler Code Committee of the American Society of Mechanical Engineers as Specification S-28 for the construction of riveted or seamless pressure vessels. Short time tests indicate that it has a creep strength approximately 50 per cent higher than that of plain carbon steel at a temperature of 1000 F. Its resistance to oxidation at elevated temperatures is definitely better than that of plain carbon steel but it is not of the same order as that of the higher alloy steels.

Steels for Other Power Plant Uses

In addition to the steels which are suitable for boiler drums, superheater tubes and steam pipes operating at high temperatures, there are a number of alloy steels that are well adapted for use in other parts of the power plant equipment.

Bolts for high-temperature, high-pressure service are a real problem. They must be heat treated in order to have the necessary high strength and they must not lose this strength at the temperature at which they are to be used. Several alloy steels are proving satisfactory for this type of work. Probably the most satisfactory steels for this application are the chromium-molybdenum steels containing from 0.5 to 1.5 per cent chromium and from 0.2 to 0.6 per cent molybdenum.

Nickel-chromium-molybdenum, chromium-nickel and nickel-molybdenum steels of various compositions have also proved satisfactory. The addition of tungsten and vanadium to some of these steels has still further enhanced the advantages they possess for high-temperature work but it is obviously impossible to go into detail regarding so many modifications.

Alloy steels are necessary not only for the equipment used for generating high-temperature, high-pressure steam but are equally necessary for the proper operation of other units of the power generating equipment. A modern turbine using high-temperature steam could not be built without the use of alloy steels. For certain parts of these turbines, such as the blades, the steel must possess not only high creep strength and resistance to oxidation, but must resist erosion as well and must be capable of being worked into the necessary shapes. Some of the high chromium and high nickel-chromium alloys have shown themselves to be particularly suitable for this service. In the boiler plant, alloy cast irons containing chromium and nickel have greatly increased the life of stokers and other parts subjected to oxidizing conditions at high temperatures.

The problem of metals suitable for use at high temperatures is an exceedingly complicated one and cannot be adequately discussed in a short paper. Industry is demanding materials to withstand ever increasing temperatures, pressures and corrosive conditions, and the steel maker and metallurgist are cooperating to satisfy this demand. That they have been successful in the past is obvious and there is every reason to believe that they will continue to serve adequately the needs of industry in the future.

Boiler Water Lectures

That steam engineers are especially anxious to learn more about boiler water chemistry was shown by the attendance at a series of six lectures, with laboratory demonstrations, which were conducted by the staff of W. H. & L. D. Betz, chemical engineers of Philadelphia, at the Robert Treat Hotel, Newark, N. J., over a period from May 8 to June 12. The attendance ranged from 211 at the first lecture to over 300 at the last. Each of these lectures was divided into three parts, dealing with general chemistry, water chemistry and water analysis. An ultra-microscope was set up and each person was given the opportunity of viewing colloidal particles. Preceding each lecture an hour was devoted to individual study and questions and those attending were invited to bring water samples and use the equipment set up for making analyses. It is planned to repeat the series in other sections at an early date.

A. E. White, Director of Engineering Research, University of Michigan, has been elected vice-president of the American Society for Testing Materials. Mr. White is a well known metallurgist and has long been identified with the power plant field.

At the organization meeting of the directors of The Superheater Company, held on May 17, 1935, George L. Bourne, Samuel G. Allen and Frederic A. Schaff were appointed the Executive Committee. Mr. Allen was elected chairman of the Executive Committee. Thomas F. Morris was elected secretary and assistant treasurer of the company.

Guy T. Shoemaker, formerly vice-president in charge of engineering for the United Light & Power Engineering & Construction Company, Davenport, Ia., is now with the Kansas City Power & Light Company as vice-president. He takes over the work formerly handled by Edwin Jowett, vice-president in charge of power production, who retired recently. Mr. Shoemaker will continue as electrical and mechanical engineer for The United Light & Power Engineering and Construction Company, but will handle the work through the Kansas City Office.

PLANT MODERNIZATION*

By MARION PENN

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Statements have recently appeared in the daily press purporting to show that the electric industry is faced with a serious shortage of capacity in the near future, and that a large amount of generating equipment, which is obsolete, is being continued uneconomically in service. The purpose of this paper is to point out that no such shortage exists, and that when the need for future capacity arises the less efficient peak load carrying capacity, can be converted by modernization into highly efficient base load capacity. Also that this so-called "obsolete" equipment is performing its present function of peak load carrying in an economical manner.

LET us look at actual figures as to loads and capacities based upon data furnished by utility systems throughout the country and compiled by the Statistical Department of the Edison Electric Institute. The installed electric generating capacity in utility plants was in December, 1934, 33,242,000 kw. This generating capacity though 12.5 per cent greater than in 1929, the year having the highest peak load and greatest output, produced 5.7 per cent fewer kilowatt-hours of electricity in 1934. A comparison between the heaviest week of 1929 and that of 1934 shows that if the 1934 week's output had been carried with the same operating margin of capacity as in 1929 there would have been 4,800,000 kw of installed capacity in excess of the load requirements. In other words, at the beginning of 1935 there was a surplus of available capacity awaiting future load growth of nearly 5,000,000 kw.

This statement is conservative because it is based upon the assumption that load and operating conditions at present are similar to those obtaining in 1929, notwithstanding the numerous interconnections which have been completed since that time, thereby increasing the effective capacity by reducing the amount of reserve required and also by the capacity gain due to load diversity. As an example of the effect of interconnection on the load which can be carried by a system, Public Service Electric and Gas Company of New Jersey can carry a load practically equal to the full nameplate capacity of its generating equipment without any allowance for spare. This is possible because reserve requirements have been reduced by interconnection with other large companies to the point where they are almost completely offset by the load diversity capacity afforded by these interconnections. While this does not perhaps apply to the same extent throughout the country, it does have a material effect upon the capacity required. It should be borne in mind, however, that interconnections are subject to the law of diminishing returns and that beyond a certain point interconnection with other systems does not result in much additional economy or capacity savings. Furthermore, plants under construction by utilities are not included in these capacity figures, nor are the uneconomical hydro-electric projects now being undertaken by the Federal Government, in regions where capacity is not now and is not likely to be required for any predictable future need. Since many generating systems were not loaded to the limit of their capacity in 1929 and for the reasons enumerated above, it is reasonable to assume that the true capacity surplus as of December 1934 was in excess of 5,000,000 kw.

Although it is true that there is at present an excess of generating capacity, this does not apply to the same extent to transmission and distribution facilities. It is the usual practice to start building local transmission and substation facilities one year in advance of the actual need and distribution work during the year required. This having been the case for the period in which the depression started, it appears reasonable to say that in most cases the transmission and substation plant is built one year ahead. If, however, as appears likely, the loads of the current year equal those of 1929 and 1930, distribution facilities will presently be in need of expansion.

Present Usefulness of So-called "Obsolete" Capacity

One statement which made the press releases on power shortage more startling was the alleged fact that at least 2,000,000 kw of the steam plant capacity is "obsolete" and should be scrapped. Most of this equipment, however, is now serving as spare and peak load capacity and is required to be operated only a limited number of hours during the year. Hence, its inherent inefficiency is of little consequence in its effect upon total costs.

As a general principle it may be stated that old generating equipment may be scrapped and replaced by new equipment only when the cost of system operation with

* An address before the Second Session of the Third Annual Convention of the Edison Electric Institute, Atlantic City, N. J., June 3, 1935.

the old equipment in service exceeds the sum of the fixed charges on the new equipment plus the cost of system operation with the new equipment in service, due consideration being given to salvage value. This general proposition is true from an engineering and economic standpoint. As most of the older equipment in use is entirely adequate for the peak service required of it and is performing this service more economically than would be possible with new equipment, all costs considered, it is usually impossible to justify scrapping it on an economic basis. Furthermore, the possibility of superposing high-pressure and high-temperature equipment upon older equipment when additional system capacity is needed, makes the scrapping of the older equipment economically unjustifiable. Only relatively small sizes of generating equipment, with attendant high operating labor and maintenance costs, can normally be scrapped when no longer economical for peak load service. It is therefore evident that the capacity surplus is not materially decreased by this so-called "obsolete" equipment.

Future Capacity Requirements

Under present conditions it is impossible to predict future loads with any degree of certainty, but it is our belief that the rate of load growth for the next few years will not exceed that of the years immediately preceding 1929, when the annual increase of generating capacity was approximately 2,000,000 kw. Under this condition, the present surplus of generating capacity will carry us to the 1938 peak. Of course, this applies to the country as a whole. Undoubtedly there are individual systems where capacity will be required earlier, but such situations are well recognized by the companies concerned and will be taken care of in the normal, logical way that has always prevailed in the past.

Should, for some unforeseen reason, the rate of load growth exceed that of the pre-depression period could the industry meet the situation? It unquestionably could, as a large amount of incremental capacity or superposed capacity could be added to existing plants in from twelve to eighteen months and the manufacturers of steam turbines and boilers can produce more than 4,000,000 kw of generating capacity per year. Also, under such conditions, additions could be made to existing hydro stations if such were warranted.

If a national emergency such as war should occur, is the private electric industry in a position completely to do its part? Again the answer is yes. Even during the World War the shortage of power was not very serious, and was confined to a few limited industrial areas and not generally throughout the country. Lack of or inadequate interconnection facilities between generating stations was largely responsible for this situation. Today not only are the individual plants of an area interconnected but the larger industrial areas are interconnected with adjacent areas.

How Capacity May Be Added

It has been the history of electric power generation that progress has been continuously advancing toward a greater utilization of the heat contained in the fuel. This progress has been made in steps, first by experimentation and research, and finally by the installation and practical use of the newly developed equipment.

The use of efficient apparatus to condense the steam from turbine generators goes back 25 years. With the advent of such condensers it was no longer possible to increase materially the thermal efficiency of generating units by further lowering the final exhaust pressure. Progress, therefore, has been directed toward increasing internal efficiency and raising the initial pressure and temperature of the steam before admitting it to the turbine so that there would be a greater amount of heat transformed into electrical energy before reaching the condenser. The elevation of the steam temperature and pressure has been in progressive stages and practically every large power generating system exemplifies these stages of improvement. Briefly, they may be classed as the 200-, 400-, 600- and 1200-lb pressure plants, the latter two of which are of the most recent development.

There are three principal means of adding capacity to existing systems, namely:

(*a*) By the construction of new generating stations.
(*b*) By extensions to existing generating stations.
(*c*) By superposing steam or mercury vapor equipment on existing turbine generating units.

A fourth method, that of increasing capacity of existing units or replacing them with larger units, is sometimes possible also.

Generally speaking, the building of an entirely new generating station is the most costly means of securing new capacity. Undoubtedly there are instances where there is no alternative. As such is the exception rather than the rule for immediate requirements this discussion will be confined to the adding of capacity by extensions and superposing.

Extensions to existing plants can usually be made at a cost per kilowatt of capacity which is less than that for a new plant. These extensions can be made either with the present steam conditions or at higher pressures and temperatures; the decision depending upon which is the most economical means of producing energy, all costs considered, or other practical reasons.

In considering the addition of capacity at the older plants particularly those in the 200-lb class, superposing is a practical and economical means of securing new capacity and also makes possible the efficient utilization of the low-pressure equipment. Essentially a superposed installation consists of a boiler or boilers generating steam at high pressure and high temperature, and a high-pressure turbine-generator which uses this steam and exhausts it into the older low-pressure equipment. This has been a gradual development and there have been a number of installations made and others are projected to be carried out when load conditions justify. Superposition has been and is now receiving the active study of the electric light and power industry.

Superposed installations using high-pressure and high-temperature steam, or mercury units, will usually cost per kilowatt of increased system capacity not more than, and probably less than, the cost of an entirely new generating station with units of comparable size. The proportion of high-pressure capacity which may be superposed upon low-pressure capacity ranges from 60 to 100 per cent, depending upon the high pressure employed and the pressure at which the older plant operates. The amount of capacity which is superposed will depend upon the amount of low-pressure capacity which it is economical to modernize as compared to other methods of in-

creasing capacity, and will vary widely for different systems. The older plants where superposition can be made, are located at established load centers, and existing transmission and distribution facilities can be utilized partially at least in connection with the new capacity. The saving in system capital expenditures thus effected becomes a credit to the superposition plan.

Steam boilers for operation at 1400-lb pressure and 1000 F are available without any change in basic principles of conventional design with natural circulation. Boilers of capacity for 1,200,000 lb per hr steam flow are in operation and boilers for a flow of 2,000,000 lb per hr have been projected. They are suitable for use either for superposed capacity or for completely new condensing plants.

High-pressure exhaust turbine generating units running at 3600 rpm are available in sizes ranging up to 50,000 kw, the size selected depending upon the capacity of the low-pressure generating units which it is desirable to operate in combination with it. Lower speed machines are available in still larger sizes. The availability of the superposed unit is high because it has practically no auxiliaries. It is also relatively small and low in mass, and the temperature differential between the inlet and the outlet ends is not great compared to a condensing unit operating with the same initial temperature. The combination of high- and low-pressure capacity is high in availability also for the reason that if more than one low-pressure unit is connected to it, the low-pressure units may be alternately taken out of service for maintenance without interrupting the service of the high-pressure unit.

Other causes of lower efficiency, those resulting from the less efficient cycle and poorer inherent turbine and condenser design, can usually be corrected at a cost of a few dollars per kilowatt. The resultant modified unit will have an efficiency usually not more than 3 per cent lower than a similar machine built today. If we assume that the superposed capacity is equivalent to 75 per cent of the low-pressure capacity the combination of capacity will be only $1^3/_4$ per cent less efficient than an entirely new unit of comparable size. It is evident, therefore, that superposing is a most attractive means of modernizing existing generating equipment.

Usually it is not economical to attempt to modernize existing low-pressure boiler units for efficiency gain alone. Where it is necessary to operate a low-pressure boiler plant and where the installation of high-pressure equipment cannot be justified it may be possible that a study will indicate improvements which can be made. Examples of this are the conversion to pulverized coal or oil firing from other types of firing and the addition of water walls with consequent increase in steaming capacity.

Modernization of Public Service System

A brief résumé of the improvements made in the generating stations of Public Service Electric and Gas Company within the past few years and what is contemplated for the future will serve to illustrate some of the means of modernization. Other companies are making improvements along the same or different lines.

At Burlington Station a superposed unit consisting of a high-pressure boiler and an 18,000-kw turbine-generator, operating in conjunction with three older 200-lb pressure units has been installed. It has made available to the system 56,000 kw of highly efficient capacity and is in line with future extensions providing for the installation of four 100,000 kw condensing units. The older boiler plant is held in reserve for the operation of the low-pressure turbines when the high-pressure boiler is out of service.

At Essex Station eight boilers have been equipped for fuel oil firing and for the past two years have carried practically the entire load required of the station. Studies have been made for the installation when needed, of two 50,000-kw high-pressure superposed units which will operate in conjunction with an equal amount of the existing low-pressure generating capacity. The heat rate of the combination will be about 11,300 Btu per kw-hr. Space for the new boilers and turbine-generator units will be provided by the removal of eight of the present stoker-fired boilers. It is interesting to note that fourteen studies were made on this installation before reaching the present plan for modernization, emphasizing the fact that system development is a continuous process, requiring an intimate knowledge of system conditions. No outside agency would be qualified or competent to carry on such a study of system development.

At Kearny Station there has been installed a 90,000-kw turbine-generator operating at the normal steam conditions of the plant. The steam required by this unit has been provided by the addition of partial water walls and new superheaters to the original twelve boilers. Three large boilers have been equipped and operated with oil firing. A mercury-vapor turbine generating unit of 20,000-kw capacity has been installed and from a mechanical standpoint has been operating satisfactorily. The only difficulty now being experienced with this installation is of a chemical nature. Oxides are being formed within the mercury boiler which have been troublesome in that these oxides plug up the tubes and other spaces within the circulating system, causing occasional tube failures. This is, however, being given constant study by the manufacturer, both in the field and in the research laboratory and from all indications within a short time this difficulty will be overcome. The installation, which has operated at a capacity factor of 30 to 40 per cent since it went in service, gives results when in operation fully up to design expectations. It is probable that another mercury turbine and steam turbine will be added to Kearny without the necessity of additional steam boilers when more capacity is needed at that station.

At Marion Station, started in 1905, it is planned to install in the future a superposed boiler and turbine-generator unit of 50,000 kw capacity to operate in conjunction with three low-pressure horizontal units. Twenty of the old boilers at this station have been equipped and are operated with fuel oil, and these will be used for peak load operation of the vertical turbine-generators in the station. These thirty-year old boilers have been operating on oil for three years at efficiencies above 80 per cent.

The Perth Amboy plant, consisting of two 5000-kw turbines installed in 1911, and one 10,000-kw turbine installed in 1918, is used only on peak about two months during the year when load conditions require it. It has not been found possible to discontinue its use, however,

as its replacement would cost more in fixed and operating charges than its present operating cost. Due allowance has of course been made for the economical energy which the replacement equipment would carry. We are now making studies of superposing 1800- to 3000-lb pressure steam upon this old equipment, and have found that 25,000 kw of new turbine capacity at 3000 lb with a Benson type boiler would carry the entire old plant with a resulting heat rate of 12,300 Btu per kw-hr.

Exact costs have not been determined, but it appears now that it would cost not more than the average cost for a new condensing plant if credit is given only for the new capacity added. If the plant had reached the end of its economical usefulness as a peak carrier, and on that basis was being considered for scrapping, then in computing the cost per kilowatt from the capital expenditure involved, the capacity or divisor should be taken as the sum of the high- and low-pressure capacities, thus resulting in low unit cost for a highly economical plant.

The Public Service generating system today has a total capacity of 685,000 kw. By virtue of load and reserve diversity resulting from interconnections it is possible to carry a firm load of 675,000 kw on the generating equipment. The peak load of 1934 was 495,000 kw leaving a surplus of capacity of 180,000 kw for load growth. A study of future possibilities shows that 200,000 kw of superposed capacity and 500,000 kw of incremental capacity can be added to the system before new stations need be built. These additions, amounting to 700,000 kw or double the existing capacity can be made at a cost per kilowatt of 80 to 90 per cent of that for a new plant, and they would entail little additional cost for transmission.

A.S.M.E. Officers Nominated

Nominations for officers of The American Society of Mechanical Engineers for 1936 were announced at a recent meeting of the Nominating Committee held at Cincinnati, Ohio, during the Semi-Annual Meeting. Election will be held by letter ballot of the entire membership, closing on September 24, 1935. The nominees as presented by the regular nominating committee of the society are:

President—W. L. Batt, President SKF Industries, Inc., Philadelphia, Pa. Vice-Presidents—A. D. Bailey, Superintendent Generating Stations, Commonwealth Edison Company, Chicago, Ill.; J. A. Hunter, Professor University of Colorado, Boulder, Colo.; R. L. Sackett, Dean Pa. State College, State College, Pa.; W. A. Shoudy, Orrok, Myers & Shoudy, Consulting Engineers, New York. Managers—W. L. Dudley, Vice-President Western Blower Company, Seattle, Wash; W. C. Lindemann, Secretary A. J. Lindemann & Hoverson Company, Milwaukee, Wis.; J. W. Parker, Vice-President and Chief Engineer, Detroit Edison Company, Detroit, Michigan.

The production of electricity by the electric light and power industry for June 1935, as reported by the Edison Electric Institute, was not only 4.6 per cent above that for the corresponding weeks of last year but exceeded the outputs of the corresponding periods for 1929 and 1930 by 2.5 and 2.6 per cent, respectively.

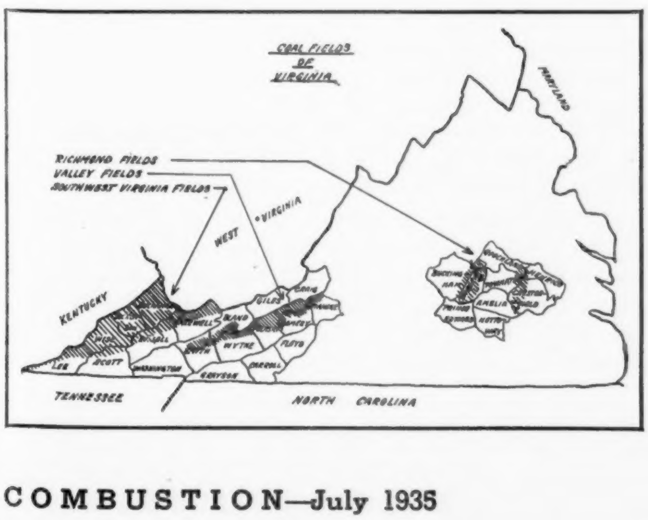
Virginia Coals—
Their Classification and Analyses

By P. B. PLACE
Combustion Engineering Company, Inc.

This is the fourth of a series of articles discussing the location, analysis and characteristics of various coals of the United States. Ohio and Kentucky coals have been covered. The present article identifies the different seams and the trade names of Virginia coals, reviews their qualities and lists their importance from a production standpoint.

VIRGINIA has several coal deposits scattered throughout the state. Three of these are shown in Fig. 1 and are called the Richmond Basin, the Valley and the Southwest Virginia Fields, respectively. The Richmond Basin field yields good bituminous coal and is of interest in that it was one of the first fields in this country to be worked commercially. Very little coal is produced here at present. The Valley Fields yield coal varying from bituminous to semi-anthracite and was one of these fields that supplied the coal used by the Confederate boat *Merrimac*, the first iron-clad battleship. The bulk of the Virginia production is from the Southwest Virginia field in Wise, Tazewell, Lee, Dickenson and Russell counties and this field yields high-grade, low, medium and high volatile coals valued as steam and coking fuels and comparable to similar coals mined in West Virginia and eastern Kentucky. Table I gives an outline of the principal coal fields of Virginia and the counties in which they occur.

The total bituminous coal produced by Virginia is only two to three per cent of the total production of the United States and the state ranks eighth on a production basis. The Southwestern Fields contribute 97 to 98 per cent of the state production and of this; Wise, Tazewell and Lee Counties account for 75 to 80 per cent. Tables II and III give the relative bituminous coal production of the principal states and of the principal counties of Virginia during recent years.



The coal bearing rocks of the Southwestern Field contain twenty-five or more different coal seams and have

TABLE I

COAL FIELDS OF VIRGINIA

I. Southwest Virginia Fields
  A. Pocahontas or Flat Top Field
    1. Tazewell County
    2. Northern Buckanan County
  B. Clinch Valley or Big Stone Gap Field
    1. Wise County
    2. Tazewell County
    3. Lee County
    4. Dickenson County

II. Valley Fields
  A. Brushy Mountain and Price Mountain Fields
    1. Montgomery County
  B. Little Walker and Pulaski Fields
    1. Pulaski County
  C. Max Meadows and Reed Creek Fields
    1. Wythe County
    2. Bland County

III. Richmond Basin Field
    1. Cumberland County
    2. Chesterfield County
    3. Henrico County

been grouped into five formations geologically named as follows:

Harlan Sandstone Formation (top)
Wise Formation
Gladeville Sandstone Formation
Norton Formation
Lee Formation

The principal coal seams occur in the Wise, Norton and Lee formations which are each over a thousand feet thick as compared with the sandstone formations which are about a hundred feet thick.

The nomenclature of the formations in Virginia is the same as used in Kentucky and many of the coal seams in the Wise and Norton formations of both states have been correlated, though often designated by different names. Table IV gives the names of the principal seams in Virginia listed in their descending order. Many of the Lee County seams are known by numbers as indicated in the Table, although the same seams in adjacent

TABLE II
RELATIVE PRODUCTION OF BITUMINOUS COAL
IN PRINCIPAL COAL PRODUCING STATES
1929 - 1932
PER CENT OF TOTAL BITUMINOUS PRODUCTION

State	1929	1930	1931	1932
West Virginia	25.9	26.0	26.5	27.7
Pennsylvania	26.8	26.6	25.6	24.1
Illinois	11.4	11.5	11.6	10.8
Kentucky	11.3	11.0	10.5	11.4
Ohio	4.4	4.8	5.4	4.5
Indiana	3.4	3.5	3.7	4.3
Alabama	3.4	3.3	3.1	2.5
Virginia	2.4	2.3	2.5	2.5
	89.0	89.0	88.9	87.8

TABLE III
RELATIVE PRODUCTION OF BITUMINOUS COAL
IN PRINCIPAL COUNTIES OF VIRGINIA
1929 - 1932
PER CENT OF TOTAL PRODUCTION OF STATE

County	1929	1930	1931	1932
Wise	41.7	38.3	34.6	35.1
Tazewell	22.0	23.0	22.9	23.5
Lee	16.8	15.9	19.6	20.1
Dickenson	6.3	9.1	10.8	10.0
Russell	11.1	11.5	10.3	8.8
	97.9	97.8	98.2	97.5

TABLE IV

PRINCIPAL COAL SEAMS IN VIRGINIA

Formation	Name of Seam
Harlan Sandstone	High Splint; No. 12 (Lee Co.)
	Morris; No. 11 (Lee Co.)
	Pardee; No. 10 (Lee Co.)
	Phillips; No. 7 (Lee Co.)
Wise	Low Splint; No. 6 (Lee Co.)
	Taggart; No. 5 (Lee Co.)
	Standiford; Harlan; No. 3 (Lee Co.)
	Imboden; No. 1 (Lee Co.)
	Addington
	Alma
	Clintwood; North Fork (Lee Co.)
	Eagle
	Blair; Bentley (Lee Co.)
	Dorchester; Glamorgan; Cornett (Lee Co.)
Gladeville Sandstone	Norton
	Hagy
	Splash Dam
	Upper Banner
	Lower Banner
Norton	Kennedy
	Aily
	Raven; Red Ash
	Jawbone
	Tiller
	Burton's Ford (Scott Co.)
	Milner (Scott Co.)
	Upper Seaboard
	Lower Seaboard
	Upper Horse Pen
	War Creek
	Lower Horse Pen
	Pocahontas No. 6
	Pocahontas No. 5
	Pocahontas No. 3

counties are designated by name. Thus, No. 5 seam in Lee County is the Taggart seam of other counties in Virginia and incidently is correlated to the Elkhorn seam of Kentucky.

Wise County contains the largest and most valuable coal reserves of the state. Most of its minable seams are in the Wise, Lee and Norton formations. The coal is a high-grade coking coal, of low moisture, ash and sulphur content, running 30 to 35 per cent volatile matter and 1400 to 14,500 Btu as received. The most important seams are the Imboden, Upper and Lower Banner, Dorchester, Pardee, Taggart, Norton and Jawbone. In adjacent Scott County, the Burton's Ford seam is the only seam of more than local importance.

Although there are many seams available in the Lee and Norton formations, the best known coal in Tazewell County is the Pocahontas No. 3. This coal is the same as mined so extensively in West Virginia and is in great demand for metallurgical, steam and domestic fuel. The coal is soft and much slack is produced in mining it. The moisture, ash and sulphur are low, the volatile runs 18 to 20 per cent and the heating value is normally between 14,500 and 14,600 Btu as received.

Dickenson, Buckanan and Russell Counties have important reserves in the Norton formations but most of the production is used locally at present. Lee County has excellent quality coal in the Harlan Sandstone and Wise formations.

Average analyses of Virginia coals are given in Tables V and VI. In both tables the counties are arranged in order of their importance on a production basis and, in general, the seams are arranged in order of their importance in the counties. Following the precedent of previous articles of this series on coal,[1] the analyses in Table V are given on a moisture and ash free basis with the normal range of moisture and ash values on an "as received" basis. From this table an analysis can be set up for any known or selected values of moisture and ash, that will be fairly reliable for the seam and county in which the coal is found. When the seam is not known the average values for the county may be used, the table indicating the error that may be expected. Note that in Tazewell County, the Pocahontas seam is the most important and the average given for the County applies only to the other seams. The low volatile analyses given in Table VII are applicable to the Pocahontas coal. Table VI is a list of typical Virginia coal analyses on an "as received" basis, as given in a *Keystone Coal Catalogue*.

In the absence of specific information concerning the source of a Virginia coal, the analyses given in Table VII may be used as typical of the high, medium and low volatile coals of this state. These analyses, given on "as received," "dry" and "moisture and ash-free" basis,

[1] Analyses of Coals of the United States, COMBUSTION, October 1934; Ohio Coals—Their Classification and Analyses, COMBUSTION, November 1934; Kentucky Coals—Their Classification and Analyses, COMBUSTION, January 1935.

TABLE V
AVERAGE ANALYSES OF VIRGINIA COALS

COUNTY AND SEAM	MOISTURE AND ASH FREE								AS RECEIVED	
	VOLATILE MATTER	FIXED CARBON	SULPHUR	HYDROGEN	CARBON	NITROGEN	OXYGEN	BTU/LB	MOISTURE	ASH
WISE - IMBODEN	37.2	62.8	0.8	5.4	85.3	1.6	6.9	15230	2-3	5-8
WISE - UPPER BANNER	36.0	64.0	0.6	5.5	86.8	1.8	5.3	15410	2-3	5-12
WISE - LOWER BANNER	37.2	62.8	0.9	5.4	86.0	1.8	5.9	15340	2-3	7-11
WISE - DORCHESTER	36.8	63.2	1.4	5.5	85.4	1.7	6.0	15300	2-4	5-10
WISE - PARDEE	38.3	61.7	1.3	5.5	84.6	1.8	6.8	15085	2-4	5-10
WISE - TAGGART	36.4	63.6	0.6	5.3	86.5	1.6	6.0	15350	2-3	2-5
WISE - RAVEN	35.2	64.8	1.0	5.3	86.4	1.7	5.6	15340	2-3	5-7
WISE - JAWBONE	38.7	61.3	1.5	5.6	84.9	1.6	6.4	15020	1-3	15-20
AVERAGE	37.0	63.0	1.0	5.4	85.7	1.7	6.2	15260	1-4	2-20
TAZEWELL - POCAHONTAS #3	22.6	77.4	0.6	4.8	90.4	1.3	2.9	15765	2-4	4-5
TAZEWELL - POCAHONTAS #3	17.7	82.3	0.7	4.8	90.4	1.3	2.8	15880	3-6	3-5
TAZEWELL - RAVEN	35.0	65.0	0.7	5.8	87.7	1.4	4.4	15570	2-4	5-6
TAZEWELL - TILLER	34.7	65.3	0.7	5.3	86.9	1.5	5.6	15320	2-3	7-9
TAZEWELL - JAWBONE	36.0	64.0	0.6	5.4	87.0	1.6	5.4	15350	2-3	10-12
TAZEWELL - MEADOW	33.5	66.5	0.7	5.3	87.6	1.3	5.1	15435	2-4	10-13
TAZEWELL - UPPER SEABOARD	32.0	68.0	0.6	5.1	88.2	1.5	4.6	15660	2-4	5-7
AVERAGE*	34.3	65.7	0.7	5.4	87.5	1.5	4.9	15465	2-4	5-13
*Except Pocahontas										
LEE - TAGGART	38.5	61.5	0.6	5.5	84.0	1.5	8.4	14985	2-5	2-5
LEE - LOW SPLINT	39.8	60.2	1.2	5.4	82.8	1.9	8.7	14770	3-4	7-9
LEE - MOHAWK	38.9	61.1	0.9	5.2	84.2	1,9	7.5	15030	3-4	5-7
LEE - HARLAN	43.1	56.9	2.5	5.6	83.5	1.4	7.0	15080	2-4	4-6
LEE - PHILLIPS	40.3	59.7	0.9	5.3	82.9	2.0	8.9	14760	3-4	7-9
AVERAGE	40.0	60.0	1.0	5.4	83.5	1.7	8.4	14925	2-5	2-9
DICKENSON - UPPER BANNER	34.7	65.3	0.9	5.5	87.0	1.7	4.9	15460	2-3	4-7
DICKENSON - KENNEDY	29.7	70.3	0.8	5.1	88.3	1.8	4.0	15520	2-3	7-9
AVERAGE	32.2	67.8	0.9	5.3	87.7	1.7	4.4	15490	2-3	4-9
RUSSELL - UPPER BANNER	39.1	60.9	0.6	5.6	86.5	1.6	5.7	15400	2-4	5-8
RUSSELL - LOWER BANNER	37.4	62.6	0.7	5.6	86.4	1.7	5.6	15450	1-3	5-7
RUSSELL - KENNEDY	36.5	63.5	2.3	5.5	84.7	1.6	6.9	15000	2-5	5-25
AVERAGE	37.7	62.3	1.1	5.6	85.9	1.6	5.8	15230	1-5	5-25
SCOTT - BURTON'S FORD	34.1	65.9	1.1	5.2	85.7	1.4	6.6	15170	2-3	5-8
SCOTT - DUNCAN	36.8	63.2	0.9	5.6	84.3	1.6	7.6	15090	2-4	5-9
SCOTT - MILNER	36.3	63.7	1.8	5.4	84.4	1.8	6.6	15090	3-4	5-7
AVERAGE	35.7	64.3	1.3	5.4	84.8	1.6	6.9	15115	2-4	5-8

TABLE VI
PROXIMATE ANALYSES OF TYPICAL VIRGINIA COALS
(FROM KEYSTONE COAL CATALOGUE)

COUNTY AND SEAM	AS RECEIVED						MOISTURE AND ASH FREE	
	MOISTURE	ASH	VOLATILE MATTER	FIXED CARBON	SULPHUR	BTU/LB	VOLATILE MATTER	BTU
WISE - UPPER BANNER	2.5	5.9	32.3	60.2	0.5	14400	34.9	15560
WISE - LOWER BANNER	2.6	5.1	34.5	57.8	0.7	14150	37.4	15330
WISE - KENNEDY	2.8	6.7	33.9	56.6	1.0	13700	37.5	15150
WISE - TAGGART	2.1	2.2	35.0	60.7	0.5	14710	36.6	15380
WISE - IMBODEN	2.2	6.5	33.1	58.2	0.7	14000	36.3	15330
WISE - RAVEN	3.2	5.7	28.9	62.2	0.7	14300	31.7	15710
TAZEWELL - POCAHONTAS #3	2.9	4.4	21.2	71.5	0.6	14550	22.9	15700
TAZEWELL - RED ASH	3.2	5.7	28.9	62.2	0.7	14300	31.7	15710
LEE - TAGGART	3.7	2.8	36.3	57.2	0.6	14030	38.8	15010
LEE - IMBODEN	2.2	6.5	33.1	58.2	0.7	14000	36.3	15330
RUSSELL - UPPER BANNER	2.5	6.4	35.5	55.6	0.6	14150	39.0	15550
RUSSELL - LOWER BANNER	2.5	5.1	34.5	57.9	0.7	14150	37.4	15330
MONTGOMERY - MERRIMAC	2.6	17.9	9.2	70.3	0.6	12150	11.6	15270
PULASKI - LANGHORNE	3.0	23.3	10.0	63.8	0.3	11260	13.6	15270

TABLE VII
AVERAGE ANALYSES OF VIRGINIA BITUMINOUS COALS

			AS RECEIVED	MOISTURE FREE OR DRY	MOISTURE AND ASH FREE
1. HIGH VOLATILE BITUMINOUS					
Wise Co	Imboden	M	2.5	-	-
Lee Co	Upper Banner	A	6.0	6.15	-
Russell Co	Lower Banner	Vol.	34.50	35.38	37.7
Scott Co	Dorchester	F.C.	57.00	58.47	62.3
	Pardee		100.00	100.00	100.0
	Taggart				
	Raven	S	0.91	0.94	1.0
	Jawbone	H	4.94	5.07	5.4
	Duncan	C	77.87	79.87	85.1
	Milner	N	1.56	1.60	1.7
	Low Splint	O	6.22	6.37	6.8
	Mohawk		91.50	93.85	100.0
	Harlan				
	Phillips	BTU	13880	14235	15170
	Kennedy				
2. MEDIUM VOLATILE BITUMINOUS					
Tazewell Co	Raven	M	2.5	-	-
Dickenson Co	Tiller	A	7.0	7.18	-
Buchanan Co	Jawbone	Vol.	29.95	30.72	33.1
Henrico Co	Meadow	F.C.	60.55	62.10	66.9
	Upper Seaboard		100.00	100.00	100.0
	Upper Banner				
	Kennedy	S	0.91	0.93	1.0
		H	4.80	4.92	5.3
		C	79.10	81.12	87.4
		N	1.54	1.58	1.7
		O	4.15	4.27	4.6
			90.50	92.82	100.0
		BTU	13985	14345	15455
3. LOW VOLATILE BITUMINOUS					
Tazewell	Pocahontas #3	M	4.0	-	-
Buchanan		A	4.0	4.17	-
		Vol.	18.40	19.17	20.0
		F.C.	73.60	76.66	80.0
			100.00	100.00	100.0
		S	0.64	0.67	0.7
		H	4.42	4.60	4.8
		C	83.17	86.63	90.4
		N	1.20	1.24	1.3
		O	2.57	2.69	2.8
			92.00	95.83	100.0
		BTU	14555	15160	15820

have been made up from county averages and are weighted on a basis of production. This has been done on the assumption that a coal of unknown origin is more probably a part of the major production than of the minor, and an analysis favoring the major production is more applicable.

New Officers of N. D. H. A.

At the 26th Annual Convention of the National District Heating Association, in Philadelphia, June 11 to 14, the new officers elected were: President, R. L. Fitzgerald, Duluth Steam Corp.; First Vice-President, Melvin D. Engle, Edison Electric Illuminating Co. of Boston; Second Vice-President, T. E. Purcell, Duquesne Light Co.; and Third Vice-President, J. R. McCausland, Philadelphia Electric Co.

Measures Expansion of Metals to Ten Thousandths of an Inch

In the Schenectady Works Laboratory of the General Electric Company there is a dilatometer, an instrument which measures and records in ten-thousandths of an inch, the expansion and contraction of metals as they are heated and cooled. The device was built from specifications of the United States Bureau of Standards for use of the company in its investigations regarding metals, and is not a device the company is marketing.

The dilatometer consists of a small cylindrical furnace surrounding a quartz tube—the quartz withstanding high temperatures and having a minimum of expansion when heated. A round core of about the size of a thick pencil and made of the metal to be tested is placed within the tube, which is then electrically heated up to 1800 F. On top of the specimen is placed another smaller quartz tube, sealed at both ends, to transmit the dilation of the specimen to a dial gage. The gage is connected by an Invar clamp to the outside quartz tube, and can be read to 0.0001 in.

Metals do not expand in an even, gradual way as the temperature is increased, investigations have shown. Instead, they react in an irregular fashion, expanding in spurts. Often, when a certain temperature is reached, the metal under test will contract in spite of increased heat, and then once more expand at a still higher point of the heat scale.

With the dilatometer such irregularities can be determined accurately. In welding, brazing or heat treating, information on the reaction of the metals involved to heating and cooling is very valuable. In welding, for example, where one metal is being joined to a different one, the two should cool at approximately the same rate or be heated in a manner to compensate for difference in cooling rate. If one of the metals should cool faster than the other, it would shrink away from the weld and either crack or weaken the joint.

If it is known in advance, a variation in the rate of expansion or contraction can be taken into account by carefully controlling the temperatures of each metal. Complications arising from irregularities shown in the way certain metals respond to heat at critical or irregular points may also be avoided through proper heat adjustment.

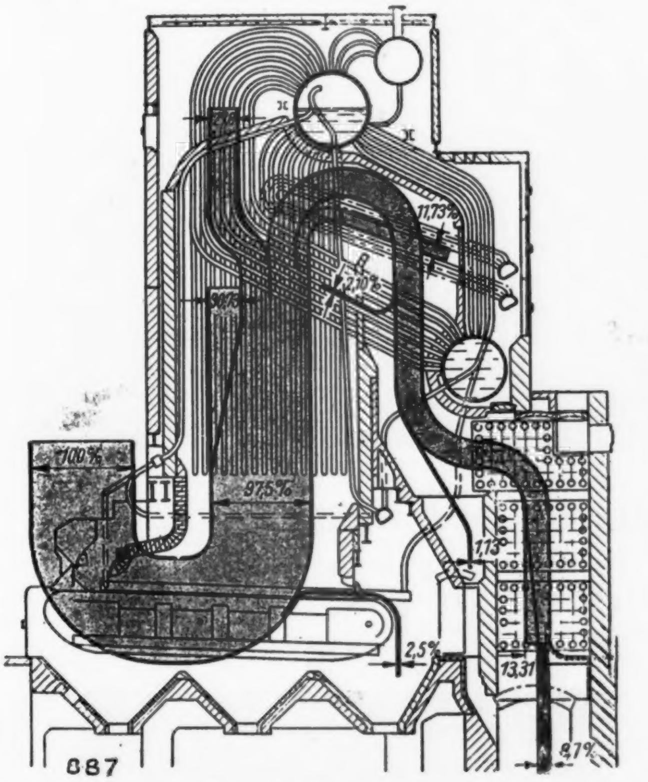
By testing various alloys of different compositions with the dilatometer, it is possible to tell how individual elements are affected by heat variations.

STEAM ENGINEERING ABROAD

As reported in the foreign technical press

Performance of Durr Boiler

Engineering and Boiler House Review (London) for June quotes from an article in *Wärme* giving the performance of a new two-drum Durr boiler (German design). This boiler, a cross-section of which is here reproduced, has a rated capacity of 40,000 lb of steam per hour at 425 lb pressure and 750 F steam temperature and is fired by a forced-draft traveling grate stoker. Water walls and a ribbed-tube economizer are provided. When burning bituminous stack having a heating value of 12,450 Btu per lb at the rate of 28 lb per sq ft of grate surface per hour and evaporating 11 lb of water per square foot of heating surface from feedwater leaving the economizer at 370 F, an overall efficiency of 85.67 was obtained. The distribution of heat flow is shown in the diagram superimposed on the boiler cross-section.



Section through Durr boiler with heat flow diagram superimposed

Determining Sulphur in the Atmosphere

A convenient method for obtaining a measure of sulphur pollution in the atmosphere is described in a recent report of the Department of Scientific and Industrial Research (Great Britain) which is discussed in the June issue of *The Steam Engineer.* The procedure under this method is to expose cylinders coated with lead peroxide paste at the selected sites, the cylinders being withdrawn for analysis of the coating at the end of a month and new cylinders substituted. This method is not designed to meet cases where it is desired to determine the volumetric concentration of the sulphur in the air and its variation from day to day, but it does provide a convenient and inexpensive means of ascertaining the comparative activity of the sulphur gases from month to month.

First Fusion Welded Boiler Drums in Great Britain

What is believed to be the first boiler installation in Great Britain incorporating fusion welded boiler drums has lately been placed in service at the plant of W. J. Bush & Co. at Hackney and is described in the May issue of *The Fuel Economist* (London). The boiler is of the two-drum type, the drums being connected by a single bank of nearly vertical tubes. Feedwater enters the main steam and water drums near the ends, thus supplying directly the down-take tubes located at the ends. These down-take tubes are not exposed to the hot gases, hence those tubes forming the actual heating surface are all free to act as steam risers.

The unit operates at 415-lb pressure, 615 F steam temperature and is of relatively small capacity—20,000 lb per hour maximum. The top drum is 15 ft long, 45 in. diameter and $1^1/_2$ in. thick and the bottom drum slightly smaller. An auxiliary steam drum, or receiver, of still smaller size is located above the main steam.

While fusion welded boiler drums are now common in this country and on the continent, England has been slow to adopt this method of fabrication and it was necessary to secure the approval and support of the insurance companies before making this initial installation.

Fineness and Flame Propagation

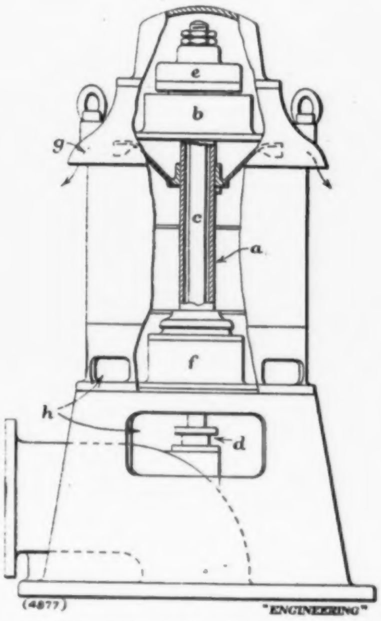
The effect of fineness of coal dust upon its rate of flame propagation is discussed by H. E. Newall in the June issue of *Fuel in Science and Practice* (London). Investigations are cited showing that the volume of oxygen absorbed by the coal increased with increasing specific surface, but the absorption of oxygen was not directly proportional to the coal surface. The rate of propagation of the zone of combustion also increased with increasing fineness, but a degree of fineness was reached beyond which further subdivision of the particles did not increase the rate of combustion. The experiments indicated

(Continued on page 35)

(*Continued from page 33*)
further that the effect of the larger particles in interfering with the propagation of heat between the finer and the more reactive particles was a more important factor in causing the optimum rate of combustion than the relatively slower rate of oxidation and consequent decreased production of heat by the larger particles.

Hollow Shaft Pump Motor

The usual method of driving a vertical-spindle pump is to connect it to a vertical motor through a flexible coupling. The pump thrust and weight are then taken up by thrust and guide bearings. A motor that has recently been designed by the British Thomson-Houston Company, and described in *Engineering* of June 14, is fitted with a hollow shaft *a* and a heavy ball thrust



A heavy ball thrust bearing takes the thrust of the pump

bearing *b* which takes the total thrust of the pump. Thus, the top thrust bearing of the pump and the flexible coupling are eliminated and the motor can be mounted on a shorter frame. The pump shaft *c* extends up through a stuffing box and guide *d* and the hollow motor shaft to a coupling *e* at the top of the motor thrust bearing. It is claimed that this arrangement has the advantage of permitting all adjustments of the pump clearances to be made from an accessible position.

Large Traveling Grate Stokers

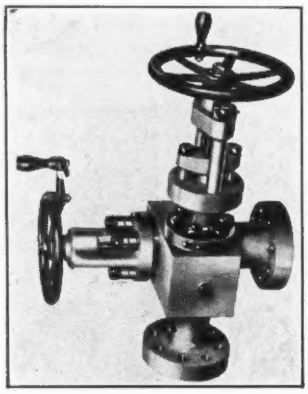
The Klip generating station of the Victoria Falls and Transvaal Power Company, South Africa, is about to install eight traveling grate stokers of the twin type 33 ft wide and 20 ft long. Each half of the stoker has a separate drive, eight rates of speed being provided. Zoned control of the air is provided and the stoker, although designed for balanced draft operation, can be run under natural, forced or induced draft. One of these units was recently shown at the British Industries Fair, Birmingham, and is described in *Engineering* of May 24.

NEW EQUIPMENT

of interest to steam plant engineers

New Yarway Tandem Blowoff Valve for High Pressures

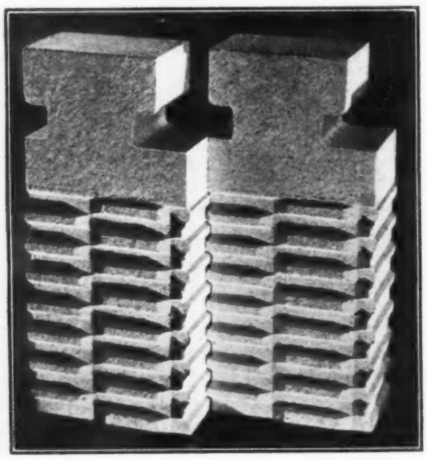
Yarnall-Waring Company, Philadelphia, has just brought out a new Yarway forged steel tandem blowoff valve designed for two pressures, namely 600 lb and 1500 lb, the lower pressure unit being suitable also for 400-lb service. This



valve has a hard seat and utilizes special alloys and construction features to reduce materially the wear incident to this type. A one-piece forged steel billet serves as the common body for both valves and into this billet flanged forged steel inlet and outlet nozzles are screwed and welded. Flanges, bolts and gaskets are thus eliminated.

Corrugated Suspended Arches and Walls

A new design of refractory for suspended arch and wall construction has been developed by M. H. Detrick Company, Chicago. This is different from the former



T-slotted construction in many ways. It is approximately one-half the size of the T-slotted tile and the faces of the tile are covered with corrugations or treads which mesh together with those on adjacent tile. The corrugations on the refractories themselves are so designed that the longitudinal joints in an arch and the vertical joints in a wall can be either straight line or offset. The construction is designed to reduce spalling in two ways: first, by making the tile smaller, better molding and a more uniform burn through the interior of the tile is obtained; second, when spalls do take place, and they usually happen diagonally across the corner of a refractory, the spalls in individual tile are held in place by the corrugations on the adjoining tile and cannot fall out. Furthermore, the intermeshed faces of the tile eliminate the possibility of furnace gases, or flames, working up through the refractory with a plus pressure condition. The staggered joints both in the arch and the wall eliminate the possibility of molten slag running along the joint and cutting it out.

New Air Filter

An air filter has recently been brought out by the R. P. Adams Co., Buffalo, N. Y., which makes use of a new principle in the separation of water, oil and other foreign materials from compressed air. It employs a combination of the centrifugal separator and the diffusion through a highly porous filter medium which retains its pore shape even though completely saturated. The air enters through an orifice located on the upper rim of the shell and circles around the inner rim at high velocity throwing out the oil, water and other liquid entrainment into vertical slots by centrifugal force. As the air slows down in velocity, it approaches the center axis and passes through the walls of a highly porous filter stone molded in the shape of a tube closed at one end. The open lower end of this tube is mounted on a hollow pedestal allowing the filtered air to pass downward and out the exit. The filter tube is composed of aluminum oxide crystals mixed with a ceramic bond and molded into the tube shape. It is vitrified in an oven at 1300 C with the resultant porosity of 38 per cent of its total volume.

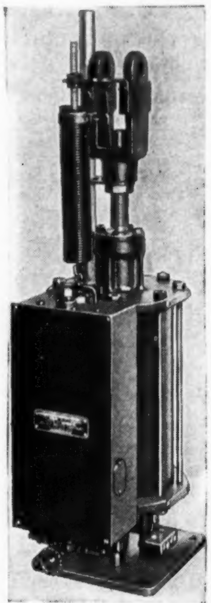
New Combustion Control for Small Plants

A simplified air-operated combustion control has been developed by Bailey Meter Company of Cleveland, for application to small industrial boiler plants.

The demand for steam is measured by variations in steam pressure and the rate of combustion is varied accordingly by the simultaneous control of fuel and air, in which the steam flow-air flow relation of the Bailey boiler meter is utilized to readjust fuel or air supply so as to continuously maintain maximum combustion economy.

The control system is based upon the measurement of all factors involved by standard Bailey recorders in which are incorporated frictionless free floating air pilot valves.

The pilot valve shown is used for operating control drives of the type illustrated. Two outlets are connected to the control



drive cylinder so that when the pilot valve is in a neutral position, as illustrated, the air pressure supplied to each side of the piston produces equal opposing forces and, therefore, the piston remains stationary. Should the pilot be moved slightly in either direction, increased air pressure would be admitted through one port to one side of the piston and air would be exhausted from the other side through one other port.

Complete flexibility of the control system is provided by selector valves on the master and individual boiler panels. These selector valves provide for complete or partial automatic control, manual control and boiler load adjustment. The position of equipment under control is indicated by a pointer and dial on the selector valve.

Stainless Clad Steel Welding Welds

This new development by the Midwest Piping & Supply Company, St. Louis, Mo., represents a stainless clad steel welding all formed from a ply plate consisting of

a mild steel foundation having a thin surface of true stainless steel. The latter is either the lining of the fitting to protect the mild steel covering from the action of

the fluid, or it forms the outer covering to protect the inner mild steel from external corrosive conditions. Stainless steel welding rod is used for the longitudinal weld of the stainless surface, and high tensile rod for the carbon steel. These fittings are available in all the customary sizes.

Flocontrol Valve

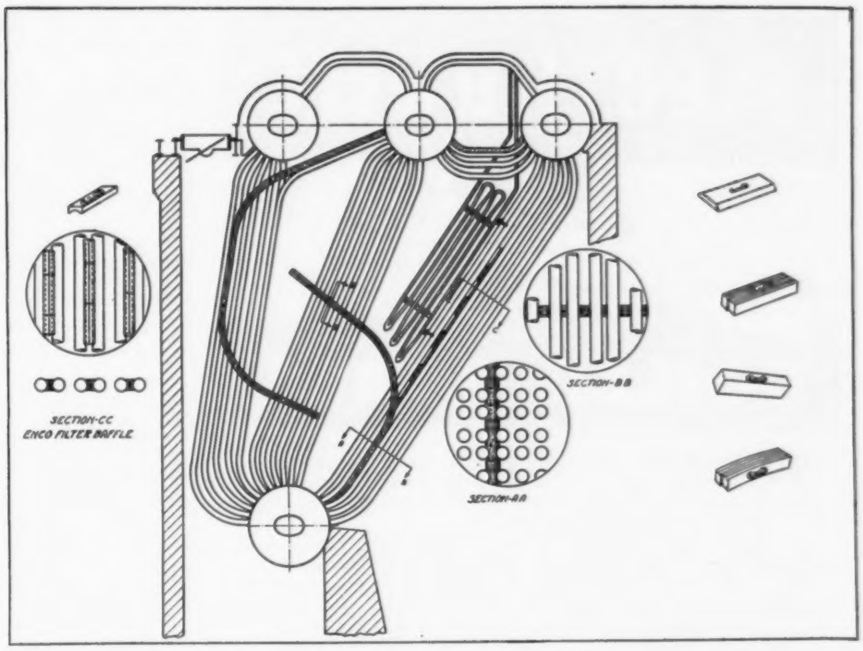
A new design of valve with a special slotted seat, in which the flow is directly proportional to the turns of the handle, has been brought out by the Consolidated

Ashcroft Hancock Company, Bridgeport, Conn. A micrometer adjustment permits the valve being regulated to one-tenth of a turn, and straightline control is thus provided. That is, if the valve is set at two turns open, then twice as much steam or liquid will pass through it as when it is set at one turn. It is made with a bronze body for pressures up to 300 lb, in either the globe or angle types, and in sizes from $^3/_8$ in. to 2 in.

Enco Filter Baffle

The accompanying sketch shows the new filter baffle arrangement recently brought out by The Engineer Company, New York, as applied to a bent-tube boiler. The removable tile is used to provide openings in the baffles for the removal of tubes. The shapes of these tiles and their placement are apparent from section AA.

It will be noted that the front baffle is placed between successive pairs of tubes as indicated in section CC. This



permits a restricted flow of the gases directly through the front bank of tubes and precludes any dead spaces. Moreover the ability to extend or to shorten the length of the front baffle by means of the readily removable tile permits easy adjustment to attain the desired superheat.

Self-Aligning Belt Conveyor Idler

A self-aligning anti-friction idler for troughed conveyor belts, is announced by Link-Belt Company. The new idler functions as follows in training the belt:

1. If the belt gradually crowds sidewise, it automatically causes the idler to swivel on its anti-friction-bearing pivotal mounting, and the carrying idler rolls steer the belt back to a central position, without the belt edge contacting an "actuating roll."
2. Should, however, the belt suddenly, or continuously, persist in crowding sidewise enough to engage an "actuating roll," the self-aligning idler would be positively swiveled the amount necessary to lead and retrain the belt into alignment with the adjacent stationary idlers.

These self-aligning idlers are used at intervals between the stationary carrying idlers of the conveyor, and their operation is said not to be affected either by the speed of the conveyor belt, or the load on it.

Flexible Coupling Uses Cushioning Effect

The L-R Type "IA" flexible coupling announced by the Lovejoy Tool Works, Chicago, introduces a new feature in the principle of the transmission of torque through resilient cushioning arms of a spider subject to compression. Instead of using the conventional parallel jaw surfaces where the outer edges of the jaws bear on the cushioning spider, causing premature wearing at the ends, the new coupling has convex jaw surfaces that exert a rolling pressure when bearing on the spider arms.

Utilizing the variation of compressibility with the thickness depending upon the resilient cushioning materials used, the convex surfaces proportion the spider arms so that the compression is substantially uniform, regardless of the extent to which each portion is compressed, thus each portion of the arm bears an equal share of the load. This new construction is said to increase the life of the cushioning spider approximately 50 per cent.

EQUIPMENT SALES

Boiler, Stoker, Pulverized Fuel

As reported by equipment manufacturers of the Department of Commerce, Bureau of the Census

Boiler Sales

Orders for 138 water-tube and h.r.t. boilers were placed in April and May

	Number	Square Feet
April, 1935	63	158,071
May, 1935	75	239,367
January to May (inclusive, 1935)	376	1,327,101
Same period, 1934	340	1,035,805

NEW ORDERS, BY KIND, PLACED IN APRIL AND MAY, 1934–1935

Kind	Apr., 1934 Number	Apr., 1934 Square feet	May, 1934 Number	May, 1934 Square feet	Apr., 1935 Number	Apr., 1935 Square feet	May, 1935 Number	May, 1935 Square feet
Stationary:								
Water tube	70	273,081	46	139,500	34	128,952	47	202,538
Horizontal return tubular	34	47,420	31	41,889	29	29,119	28	36,829
	104	320,501	77	181,389	63	158,071	75	239,367

Mechanical Stoker Sales

Orders for 251 stokers, Class, 4* totaling 64,789 hp were placed in April and May by 68 manufacturers

	Installed under Fire-tube Boilers No.	Fire-tube Boilers Horsepower	Water-tube Boilers No.	Water-tube Boilers Horsepower
April, 1935	77	13,652	43	18,589
May, 1935	88	12,643	43	19,905
January to May (inclusive, 1935)	402	56,014	199	78,534
Same period, 1934	399	52,662	167	68,235

*Capacity over 300 lb of coal per hr.

Pulverized Fuel Equipment Sales

Orders for 13 pulverizers with a total capacity of 62,920 lb per hr were placed in April and May

STORAGE SYSTEM

	Pulverizers: Total number	No. for new boilers, furnaces and kilns	No. for existing boilers	Total capacity lb coal per hour for contract	Water-tube Boilers: Number	Total sq ft steam-generating surface	Total lb steam per hour equivalent
April, 1935	..	..	..	.....	..	....	....
May, 1935	..	..	..	.....	..	....	....
January to May (inclusive, 1935)	..	..	..	.....	..	....	....
Same period, 1934	2	1	1	46,000	*	*	*

DIRECT FIRED OR UNIT SYSTEM

	Pulverizers: Total number	No. for new boilers, furnaces and kilns	No. for existing boilers	Total capacity lb coal per hour for contract	Water-tube Boilers: Number	Total sq ft steam-generating surface	Total lb steam per hour equivalent
April, 1935	2	2	..	17,300	1	9,300	143,000
May, 1935	11	8	3	45,620	9	51,100	433,700
January to May (inclusive, 1935)	48	29	19	239,120	40	236,868	2,124,780
Same period, 1934	27	18	9	240,210	19	192,475	2,006,700
					Fire-tube Boilers		
April, 1935	..	..	..	.....	..	.....	....
May, 1935	..	..	..	.....	..	.....	....
January to May (inclusive, 1935)	2	..	2	2,700	2	4,630	27,000
Same period, 1934	4	..	4	4,800	5	7,500	41,000

* Data not available.

NEW CATALOGS AND BULLETINS

COMBUSTION will be pleased to have any of these publications sent on request.

Bent Tube Boiler

Combustion Engineering Company, Inc., has just issued a bulletin describing its VM boiler which embodies a compact efficient design for medium-size and small plants, particularly where headroom is limited. Sizes range from 1359 to 6300 sq ft of heating surface and full information is given on all essential boiler and setting dimensions for the numerous sizes within this range. Blue-print reproductions are included showing typical settings with underfeed, chain and traveling grate stokers as well as with pulverized coal. Fusion welded drums are furnished regularly, with riveted drums optional.

Cable Accessories

As a companion book to GEA-1731, "How to Make Cable Joints," issued last year, the General Electric Company has issued a new publication, entitled "Cable Accessories." The two books should be of interest and assistance to everyone who is engaged in work that involves the jointing and terminating of insulated cable. "How to Make Cable Joints" gives clear and concise instructions for splicing, jointing and terminating all types of insulated cable. Its forty-four pages are illustrated with drawings and construction men can easily follow the instructions while on the job. The later book lists and describes all the materials required for this work such as joints, connectors, terminals, reservoirs and other materials. It has eighty pages and is complete in every respect — including prices.

Deepwell Pumps

An illustrated 8-page booklet covering deepwell turbine pumps has just been released by Worthington Pump and Machinery Corporation. Items of special interest are cross-sectional views showing details of construction, with explanatory notes, tables of sizes and capacities, and a list of the applications of this type of pump.

Electrical Thermometers

A new bulletin has been issued by Leeds & Northrup Company on the application of electrical thermometers to the "Efficient Regulation of an Air-Conditioning System." In a concise way this well-illustrated, 24-page booklet tells the owner, the architect, the engineer and the contractor what each needs to know about electrical thermometers.

Furnace Arches and Walls

"Detred" arch and wall construction, representing a new type of suspended corrugated tile, is described in an attractively illustrated catalog just issued by the M. H. Detrick Company. Typical installations are shown by both line drawings and photographs and tables of dimensions are included.

Indicating and Recording Gages

A 24-page catalog, PGA-35, has been issued by The Hays Corporation covering its complete line of dry-type pointer draft gages, inclined-tube direct-reading, U-tube and vernier scale gages, and dry-type draft recorders. The catalog is fully illustrated and contains much information on the application and functioning of these instruments.

Industrial Compressors and Vacuum Pumps

A new 32-page profusely-illustrated catalog has just been issued by Ingersoll-Rand Company covering its line of "Type 30" industrial compressors and vacuum pumps, ranging from $^1/_4$ to 15 hp and for pressures up to 1000 lb. The compressors described include single-stage, single- and twin-cylinder, and two-stage machines. Either automatic start and stop or constant speed control is used, depending upon the type of service. Compressors are listed with vertical or horizontal receivers, and with electric motor, gasoline engine, or belt drive. Numerous industrial applications are listed and illustrated. Tables of sizes and capacities are included.

Lists Air Preheater Installations

Essential information on over eleven hundred land type of Ljungstrom air preheaters, installed in twenty-seven different countries is contained in circular No. 307 issued by The Air Preheater Corporation (subsidiary of The Superheater Company). One hundred fifty-two of the installations listed are in the United States and data on each are included covering the name and place of the industry; the number, type and size of boiler; the fuel and firing equipment, date and number of air preheaters installed in each case. The compilation provides a convenient reference for those concerned with the selection of this type of equipment.

Mechanical Combustion Control

A new 32 page Data Book No. S-20 on the subject of Mechanical Combustion Control has just been published by Smoot Engineering Corporation. It contains a complete discussion of the basic problems of boiler operation and an evaluation of their importance in the final result, namely efficient steam generation. This Data Book is fully illustrated and contains a large number of full page diagrams showing the application of mechanical control to various types of boiler and fuel firing equipment.

Storage Water Heaters

ADSCO storage water heaters and storage tanks are listed and decribed in Bulletin 35-75 just issued by the American District Steam Company. Tables of sizes, capacities, weights and dimensions are included as well as shell thickness for different working pressures, based on A.S.M.E. rules. Information is also given on estimating hot water demand and the selection of the proper size of storage tank, heating element, steam trap and temperature regulator.

ADVERTISERS in this issue

Engineers Plan to Gain Recognition

Who is an engineer, and by what right does he use that title or undertake to practice engineering? At present there is no single criterion by which an engineer's qualifications can be measured, either by his fellows or by the public that uses his services. The legal status of an engineer is determined in some states by a process of examination, registration and licensing. His educational status may be indicated by a college degree, and his technical qualifications by his grade of membership in a national society of high repute. Not all engineers are licensed. Neither do they all possess college degrees nor hold membership in a technical society. From the point of view of professional solidarity the situation is chaotic.

As part of its plan to enhance the professional status of the engineer, the Engineers' Council for Professional Development has undertaken to define minimum qualifications of education and experience, the fulfillment of which will entitle an engineer to be recognized as such among his fellows and in his relations with the public. E.C.P.D. is a conference of engineering bodies directly representing the professional, educational, technical and legislative phases of an engineer's life. The participating bodies are the American Society of Civil Engineers, American Society of Mechanical Engineers, American Institute of Electrical Engineers, American Institute of Mining and Metallurgical Engineers, American Institute of Chemical Engineers, Society for the Promotion of Engineering Education, and the National Council of State Boards of Engineering Examiners.

Through its Committee on Professional Recognition, on which the participating bodies are represented, E.C.P.D. has proposed a "minimum definition of an engineer," and a "program of certification into the profession." The definition of an engineer, sets up minimum qualifications of technical education and practical experience, supported by examinations designed to establish the individual's ability to be placed in responsible charge of engineering work and to render him a valuable member of society. These proposals are now before the governing boards of the constituent bodies. When approved they will provide the criterion and the mechanism for professional recognition of engineers.

The program of certification into the profession was drafted by Dr. D. B. Steinman who represents the National Council of State Boards of Engineering Examiners on E.C.P.D. He is also a member of the Committee on Professional Recognition of which Conrad N. Lauer, president of the Philadelphia Gas Works, is chairman. The certification program recognizes the fact that the equivalent of a "grandfather clause" must be applied to permit automatic certification of those who are now recognized and accepted as engineers by legal authorities and by the profession. It also contemplates a reasonable transition period for the progressive adjustment of requirements and tightening of standards until the full program of E.C.P.D. for certification can be put into effect. Thus licensed engineers and certain members of technical societies will be automatically eligible to receive certificates according to a chronological plan up to Jan. 1, 1938 at which time the formal certification will be put into effect.